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HOW IT WORKS



YOUR SECRET SUPER POWERS
EXTRAORDINARY ABILITIES YOU NEVER KNEW YOU HAD

DA VINCI'S MARVELLOUS MACHINES



ASTEROID STORMS
How epic impacts shaped the Solar System

HOW DO YOU BUILD A BRAIN?

CAN COMPUTERS THINK FOR THEMSELVES?

+ APOLLO 1 DISASTER
COSMETIC CHEMISTRY
WEATHER BOMBS
SPOT THE ISS
OLIVE OIL

COULD A ROBOT DO YOUR JOB?

RISE OF THE MACHINES

HOW ARTIFICIAL INTELLIGENCE AND ROBOTICS ARE ABOUT TO CHANGE THE WORLD

Future
ISSUE 099
Digital Edition
GreatDigitalMags.com



COSMIC MYSTERIES
How scientists will unravel the secrets of the universe



CABLE CARS
San Francisco's iconic transport system explained



NINTENDO SWITCH
Inside the world's first hybrid gaming console



FREAKS OF NATURE
DISCOVER SOME OF THE WORLD'S WEIRDEST ADAPTATIONS

+ MISSION CONTROL BED BUGS TIPPER TRUCKS STAR FORTS BILL GATES ANIMAL TRACKS



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WELCOME

The magazine that feeds minds!



"Under the cover of night, the aye-aye moves along branches in the forest in search of its prey beneath the bark..."

Freaks of nature, page 28

Meet the team...



Charlie
Production Editor

For all our discoveries, there is still a phenomenal amount we don't know about space. Head to page 72 to discover some of the theories surrounding the many mysteries of the cosmos.



Jack
Senior Staff Writer

I was left stunned by the amazing machines that originated from the mind of Leonardo da Vinci. Get to know the Renaissance genius and his many clever contraptions on page 40.



James
Research Editor

Today's artificial intelligences can achieve things experts declared impossible just a few decades ago. Find out how these machines think and what it is they'll be considering next on page 12.



Duncan
Senior Art Editor

Is there really a superhero hidden in all of us? Could we all have superpowers? Find out how genetic anomalies have given some people incredible abilities on page 60.



Laurie
Studio Designer

Turn to page 52 to discover the inner working of the iconic San Francisco cable cars. Despite an earthquake and a proposal to shut the system down, these famous cars have kept running since 1873!



It's not surprising why so many of us are wary of the development of truly artificial intelligence systems. Decades of science fiction books and films have warned us about

what could happen if intelligent machines one day decide that they don't fancy sharing the planet with their human creators any more...

While these dystopian futures make for great entertainment, it is unlikely they will become reality. Artificial intelligence technology is still in its infancy, but even at this early stage, experts are pressing for AI to be closely monitored and regulated. Properly used, this technology has incredible potential to change the way we live and work. Find out how this will happen in our tech feature on page 12.

Also this month, take a trip on the San Francisco cable cars to uncover how these unique transports work, find out if you've got the supertaster gene, and discover some of the world's weirdest plants and animals. Enjoy the issue!

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Jackie **Jackie Snowden**
Deputy Editor

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RISE OF THE MACHINES



40

Da Vinci's marvellous machines

+ FREE POSTER
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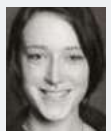
Meet the experts...



Joanna Stass

This month, Jo takes a ride through the streets of San Francisco on the city's unique cable car system. She also

explains olive oil production and the chemistry behind the irresistible aroma of freshly baked bread.



Laura Mears

This month, Laura explains how variations and mutations in our genetic code can lead to some surprising

abilities. She also gives us a quick guide to Newton's Laws of Motion in 60 second science.



Ella Carter

From bug-eyed lemurs with spindly fingers to a giant flower that reeks of rotting flesh, Ella explains the

adaptations of some of the world's strangest organisms in our environment feature.



Jonny O'Callaghan

Tackling some of the great unknowns of space science this month, Jonny explains

how we hope to find the answers to some of the biggest questions, such as: are we living in a hologram?



Stephen Ashby

This issue, Steve teaches us how to build a water filter with some household

items, and how to make a dancing snake with just some paper, a pen and a balloon.

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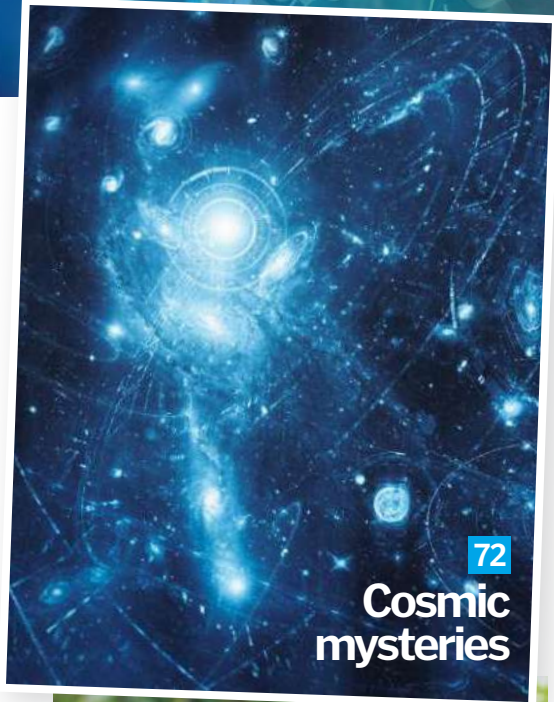
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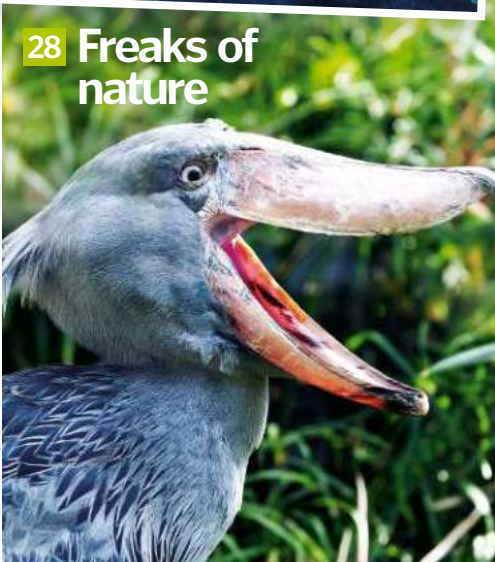
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The visible plumes of ice and gas erupt, reaching heights of around 100 kilometres above Enceladus' surface

Enceladus could have the right ingredients for life

The presence of hydrogen gas detected inside the Saturnian moon suggests it could be habitable



In an announcement in April, NASA revealed that Enceladus, an icy moon that orbits Saturn, contains hydrogen gas, which could provide a chemical energy source for alien life.

The hydrogen is produced by hydrothermal activity in the moon's subterranean oceans and erupts from the surface in icy plumes. Its presence was first detected by NASA's Cassini probe in 2015 when it took a dive through the icy spray and collected a sample. The probe's Ion and Neutral Mass Spectrometer analysed the sample, and the recently published results indicate that it is 98 per cent water, with the other two per cent comprised of hydrogen, carbon dioxide, methane and other molecules.

The hydrothermal activity is similar to that which has been observed at vents on Earth's ocean floors, which help sustain the microbes that live there. The hydrogen is converted into metabolic energy by breaking the bonds between the two atoms within the molecule and combining it with dissolved carbon dioxide in the

water. The chemical reaction is called methanogenesis and it is believed that this process may have been key to the beginning of life on Earth. The environment on Enceladus may still be too sterile for living organisms, but there is definitely scope in the future to send more missions to the icy moon to look for further evidence of life.



Enceladus is only 505 kilometres in diameter – that's smaller than the length of the UK!



Europa has streaks on its surface, which are domains composed of salt and water ice

Europa: another habitable world?

Jupiter's moon Europa has also been found to have plumes exploding from its surface. Identified by the Hubble Telescope, more information on the plumes will be collected by future missions to the icy moon.

One mission currently in development is the Europa Clipper, which is planned to launch at some point in the 2020's. It will act as a swift orbiter and is envisioned to complete up to 45 flybys of the moon. Clipper will be loaded up with a range of instruments, including a magnetometer to examine the moon's magnetic fields and an ice-penetrating radar for 3D inspections of the ice shell.

The main aim of the mission is to assess whether Europa is habitable, so the spacecraft will search for evidence of liquid water, chemical ingredients and an energy source such as hydrothermal vents.

Enceladus' frozen saltwater oceans could have the ingredients for primitive life

ICE SHELL

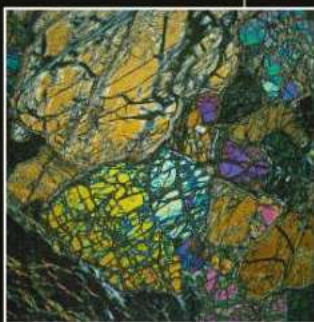
~5 km

OCEAN

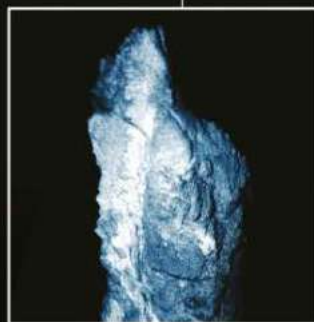
~65 km

ROCKY CORE

Hydrothermal Circulation



WATER-ROCK REACTIONS



HYDROTHERMAL VENTS ("WHITE SMOKERS")



SURFACE JETS

ENCELADUS



In the air, the flying car has a range of around 700km, with a top speed of 360km/h

AEROMOBIL REVEAL THEIR NEW FLYING CAR

The hybrid vehicle will be able to change seamlessly between driving and flight modes



According to a recent survey, two-thirds of American adults would like to take to the skies in a flying car. This dream may well soon become a reality thanks to Slovakian company AeroMobil's latest vehicle, which was unveiled at the Top Marques car show in Monaco in April this year.

The AeroMobil is constructed from a carbon composite, used in top-of-the-range aircraft and

sports cars, making it both lightweight and durable. Safety was a huge priority when AeroMobil were designing the flying car, and it is built to be aerodynamically stable and is able to deploy ballistic parachutes to bring it safely back to ground in the event of an accident. The cockpit's monocoque structure absorbs impacts to protect the pilot in the event of an accident, and the material on the wings has been pre-

impregnated with a catalysed resin to make them stronger.

The change between driving and flight modes takes just three minutes, and it's hoped the flying car can help reduce congestion by providing drivers with the choice of using the skies as an alternative highway. Costing up to an estimated \$1.2 million, pre-orders are currently being taken, with delivery scheduled for 2020.



The wings spread out from the body of the car when changing from drive to flight mode



When driving, the car can reach a top speed of 160km/h. For take off, it must travel at a minimum speed of 130km/h

+ NEWS BY NUMBERS

100
words
per minute

The proposed speed of Facebook's new 'silent speech' software

126

Number of flybys the Cassini probe made of Saturn before starting its Grand Finale

25

Public holidays in Sri Lanka every year, the highest of any country

43.6
metres

Height of the tallest ever maypole, which stood on the Strand in London in the 18th century

Delivery robots in London

A trial will test if self-driving robots can deliver purchases



The future of online shopping may be going robotic. Parcel delivery company Hermes is currently testing the capabilities of autonomous delivery robots in a London-based trial. The robots will be trialled in 30-minute collection slots and, if successful, will give companies like Hermes improved scheduling and tracking systems. A control centre monitors the robots' progress, and even though they are self-driving, a human can choose to take over in tricky situations, such as at pedestrian crossings. This trial follows on from a pilot scheme in Hamburg, Germany, which had three such robots deployed in August 2016.



The autonomous robots are an alternative to drone delivery, which is often restricted by strict aviation laws in urban areas

The giant shipworm feeds on rotting wood and lives its life buried in mud



Rare shipworm species found

A previously unstudied animal has been located by scientists in the Philippines



Scientists have recently been able to study a rare species, the giant shipworm, for the first time. The extremely rare creature can reach lengths of up to 1.6 metres and lives submerged deep in marine sediment.

Despite its name, it isn't a worm – it's actually the longest known bivalve, a group that also includes molluscs and oysters. Scientists have known of its existence since the 18th century, but this is the first live specimen ever found.

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GLOBAL EYE

Marches took place in Washington DC (pictured), London, Edinburgh, Vienna, Geneva and more



March for Science rallies hit the streets

Protestors around the world gather together in defence of scientific research



In April, huge crowds gathered to protest against political intrusion into scientific research.

Coinciding with Earth Day, the inaugural March for Science was called to address an alleged trend in the world's politicians discrediting scientific fact, while also encouraging scientists to more closely communicate their discoveries with the public. Thousands turned out for the events in a bid to stop what they believed to be political attacks on facts, especially with regards to climate change and the environment.

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How It Works | 009

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH



1

Chicago set to be 100 per cent powered by renewable electricity

The mayor of Chicago has announced that by 2025, all of the city's public buildings will be powered by renewable energy. This will be provided by wind and solar power and it would make the Windy City the biggest city in the US to have all of its public buildings powered this way.



3

Salty diets make you feel hungry, not thirsty

It's long been believed that salty food makes us thirsty, but a new study has shown otherwise. It was previously thought that the sodium and chloride ions in salt latched onto water and carried the molecules into urine. Instead, it's been hypothesised that the body's waste product, urea, prevents water from attaching to the salt. Producing urea is an energy-sapping process, explaining why a salty diet can make you feel hungrier.

2 New satellite networks could create significant space junk

As manufacturing costs decrease, more and more satellites are being launched into orbit to provide telecommunications services around the globe. The extra satellites could form 'mega-constellations' and lead to an increased risk of collisions, resulting in more space junk. Methods to de-orbit defunct satellites more quickly are currently being devised, and it's advised that new satellites are lightweight and have their own propulsion systems.



Some commuters walk a marathon every fortnight

One in nine UK commuters walk the equivalent of a marathon every two weeks. 3.5 million people spend 40 minutes a day waking to and from work, totalling a distance of almost 4.2 kilometres. Meanwhile, the typical daily commuter spends 28 minutes on foot, navigating train and bus stations, walking, and clambering up stairs or escalators.



4



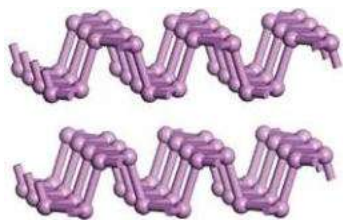
5 Medieval remedies could help fight superbugs

Scientists have turned to history books in their fight against superbugs. A new database has been set up to compile the results as experts scour the past for new antibiotics. One example is artemisinin, an ancient medicine rediscovered in 2015 that has been proved to help treat malaria.



6 The laws of physics explain why shoelaces come undone

When shoelaces unfasten, it's often down to physics rather than poor tying technique. When a high-speed camera was hooked up to a treadmill, it showed that the force of a foot hitting the ground deformed the knots, which are then loosened further by inertia. Researchers hope that the study will prove useful for considering the impact of dynamic forces on other knotted structures, such as DNA.



7 Phosphorene confirmed as new wonder material

Just like fellow wonder material graphene, phosphorene is an ultra-thin and superconducting allotrope. By pumping electrons into the layers of material, researchers found it to be an incredible electrical conductor. Excitingly, there are proposals for the material to be used as a powerful transistor in the next generation of computing.



8 Ultrasound halves the time taken to tumble-dry clothes

High-frequency sound waves can reduce the amount of time it takes to dry laundry. Rather than heating the washing like in a standard tumble dryer, the water is shaken out by ultrasonic waves, generated by transducers. A new prototype dried a medium load in just 20 minutes rather than the standard 50 minutes in conventional machines. It also used up to 70 per cent less energy than a standard dryer.

9 Early American hunters built reusable, shock-absorbing spears

13,500 years ago, the Clovis people hunted their prey with reusable spear tips that didn't snap upon impact. A small groove was cut into the base of the stone point, creating a shock-absorbing tip that crumpled instead of splintering. The durability of the Clovis point was put to the test using computer models and replicas, and they successfully withstood high pressure.



10

Songbirds change their tune depending on traffic

In areas of loud traffic, urban songbirds alter their songs to be shorter and in a lower frequency range. The noise of moving cars can obscure a song, preventing it from attracting a mate or defending territory. To counteract this, some songbirds alter the amplitude, range and length of their tunes so they can be more easily heard by potential mates and rivals.



HOW DO YOU
BUILD A BRAIN?

COULD A ROBOT
DO YOUR JOB?

CAN COMPUTERS
THINK FOR
THEMSELVES?

RISE OF THE MACHINES

HOW ARTIFICIAL INTELLIGENCE AND ROBOTICS
ARE ABOUT TO CHANGE THE WORLD

For most of us, the words 'artificial intelligence' (AI) instantly bring an image of doom to our minds. After all, we've all seen humankind extending its reach beyond its grasp before on the silver screen, and the result is always the same. All it takes is for one of us to create a machine that can truly think – one that can achieve sentience and 'wake up' – and then it's all over for humanity. What if this clever machine doesn't like the way we do things? What if it has other ideas?

It's thoughts like this that have given birth to many fantastic pieces of science fiction over the years, but in spite of what *The Terminator* may depict, AI could have more potential to help us than to harm us. But considering that respected scientists and technology experts such as Stephen Hawking and Elon Musk are warning of the potential dangers AI could pose, it's understandable if you're still sceptical.

To fully understand the amazing potential of AI, we first need to clear up the many misconceptions surrounding this exciting field of technology. To begin with, we should consider how we're able to make machines intelligent, and how it is that they think. The term 'artificial intelligence' was coined in 1956 and has come to

represent quite a broad spectrum of computer capability. The phrase is thrown around often by technology companies showcasing their latest products, but these 'intelligences' are incredibly varied in what they're able to achieve.

For the most part, artificial intelligence has become an enticing way to describe a fancy computer programme, but some truly are learning computers. The most sophisticated of these are currently confined to the stock market, the world of scientific research, or battling ever more complex games. You may think that predicting the net worth of a company, building models using genetic code and becoming a champion gamer would each require a completely different AI, but all three can be achieved using the same basic architecture.

True AI works on the principle of machine learning; the various types of which we'll explore more in this feature. Computer programmes that operate using machine

learning are markedly different to most other programmes, because you don't need to tell it how to do something – instead, you show it. Imagine you want a computer programme that can find abnormalities from brain scans. With a conventional programme, you'd have to write a very strict and detailed set of rules that it can use. But with a machine learning programme, you'd just show it a few thousand normal brain scans and a few thousand abnormal brain scans and then let the programme teach itself how to recognise anomalies.

This machine learning method certainly has its advantages over conventional programming, as the computer may well become even better than the programmer at performing its assigned task. And the most exciting part of all of this is scientists are working on programmes like these right now.

But the kinds of intelligence able to help us in our everyday lives aren't just for the world of

"The term 'artificial intelligence' has come to represent quite a broad spectrum of computer capability"

Meet the artificial brain

Humans learn by using the power of neural networks, and machines can do the same...

Sensory information

Our senses are constantly collecting huge amounts of data, which require processing by the brain.



Chemical communication

Neurons communicate with each other via chemical signals, which they send to each other across synapses.



A chain reaction

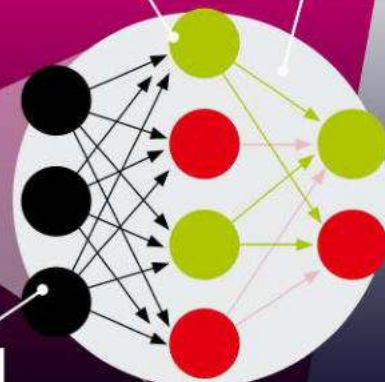
If the chemical input is strong enough the neuron will 'fire', continuing the signal along the chain.

Counting the inputs

Like the firing neuron, a node will compute the input data and only 'fire' if the value is high enough.

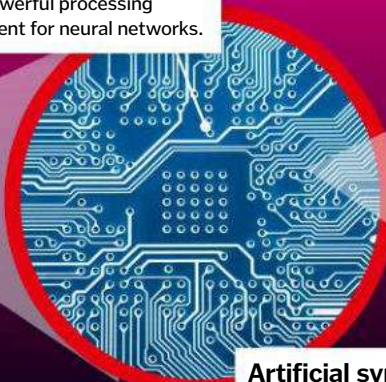
Low-level functionality

Artificial neural networks form the basis for many sophisticated types of machine learning.



Processing power

Both humans and computers have powerful processing equipment for neural networks.



Computer vision

Machines typically map visual information onto a grid, which makes data processing easier.



Artificial synapses

Artificial neural networks communicate by sending signals in the form of numerical values.



tomorrow. In fact, we're already enjoying the benefits of artificial intelligence. From Microsoft's Cortana to the mega services that are Google and Facebook, these intelligent programmes work behind the scenes to guide us through the internet. They learn about our interests, our likes and dislikes, and tailor their advertisements and recommendations for each and every one of us, which is really quite clever. And yet, despite all they can do, these are still what we would refer to as 'narrow AI'. This means that they're very good at completing one specified task – much better than a human could ever be – but they are completely unable to do anything else.

The next step on the artificial intelligence journey is to create general-purpose AI. This is where things get very exciting, or very scary, depending on who you ask. General-purpose intelligence would be much closer to human level intelligence than the AI systems that exist today, as it would be able to learn and solve

different problems and tackle different tasks. At the moment we're still a long way off achieving this dream, but Google DeepMind's AlphaGo is currently the closest we've come. This AI used its deep neural network to defeat the world's greatest Go player, Lee Sedol. This was deemed a historic moment for artificial intelligence as there are quite literally quintillions of possible moves in Go, so it would be impossible to programme them all into a computer. Instead, AlphaGo was designed to be intelligent, able to play Go against itself many times and learn from its mistakes. And after practicing over millions of games, it was good enough to go head-to-head with a champion, and win.

AlphaGo has amazing potential. Its creators talk excitedly of the programme applying its skills to assist medical experts, allowing this AI to help save lives, and its diverse way of learning could prove the basis for many clever machines.

With our current technology, this highly useful but limited AI is as far as we can go. This is

The AI ascendancy

From humble origins to world champion-beating machines, artificial intelligences have enjoyed a meteoric rise

1936

British mathematician Alan Turing publishes a paper on the 'Universal Machine', which is now recognised as the foundation of computer science.



1950

Alan Turing presents the idea of an 'imitation game' for comparing human and machine intelligence. Today, we call this the Turing Test.

1950

Science fiction writer Isaac Asimov publishes *I, Robot*. Inside this collection of short stories Asimov outlines the Three Laws of Robotics, which are designed to prevent an artificial intelligence turning on its creators. This work helped to inspire a generation of roboticists and computer scientists in their quest to create AI.



1956

The term 'artificial intelligence' is coined at a summer conference hosted by Dartmouth university.

1973

Despite the positive predictions, AI progress has stalled. Government advisors believe that machines will only ever reach an 'experienced amateur' level of chess.

1981

AI becomes a valuable commercial tool as companies employ expert computer systems for particular tasks. Some companies save millions of dollars.



How machines learn

Do they read the rules, practice, or figure it out by themselves? Actually, it's all three

Supervised learning

The computer programme is first shown a set of data that is used for 'training'. During training, the programme will learn from the rules it's given, such as: apples are red or green, and oranges are orange. Then it puts this knowledge into practice.

THIS IS AN ORANGE



AND THIS IS AN APPLE



Okay!



WHAT IS THIS?



That's an apple!



Unsupervised learning

This also involves training the computer programme with a data set, but this time, you don't tell it what the data means. After analysing lots of information (such as pictures of animals) the programme will start to recognise features and patterns in the data.

HOW MANY SPECIES OF ANIMAL ARE THERE?



I've never seen an animal before...



So there must be TWO animal species



But some are different colours...

Reinforcement learning

Google DeepMind's AlphaGo used this method to best a Go champion. It involves telling the programme what you'd like it to do, then letting it act on its own. As it progresses towards the goal it's scored higher, reinforcing those positive actions.

IF YOU WIN, YOU GET A REWARD



Oh no, I lost, I won't do that again



Practice makes perfect!



WORLD CHAMPION!



I won! Give me the reward. I'll do that again!

due to the fact that as we march from general-purpose AI towards human level intelligence, we'll need more and more powerful computers; and we've yet to invent something that can rival the processing power of the human brain.

But we wouldn't be human if we didn't rise to the challenge, and scientists are currently working on new computers that have the potential to be extremely powerful. These are known as quantum computers, and they take advantage of nature's 'spooky' properties to work in amazing ways. The speed at which they can make calculations is mind-blowing.

A good way to compare a normal computer with a quantum computer is to imagine the

centre of a maze. When the task is to escape, a normal computer will try each path one at a time, until it follows the right route and escapes. But a quantum computer can search every path at the same time. This means it is much quicker and much more powerful, and could be the key to unlocking an equivalent, or greater, power than the human brain when coupled with a sophisticated artificial intelligence. We can only wonder what awaits us on the outside of the quantum computing maze; we may achieve human level intelligence, or perhaps even greater. We may even create a super intelligence, one that surpasses our own cognitive abilities. This probably sounds both exciting and

Building a sentence

With the phonemes arranged, the software constructs the sentence. To make the most accurate guess it arranges the words like links in a chain, and uses statistical analysis to work out the most probable word sequence.

Assigning meaning

This is where the learning part comes in. Depending on the context, there may be more than one way of interpreting the sentence. If the programme misinterprets your request it will store the data so it can learn from its mistakes.

Artificial assistants

How smart virtual assistants use AI to make our lives that little bit easier

Radio waves

The best virtual assistants are equipped with voice recognition software. This uses an audio capture device to record the sound waves of your speech. This is then sent to the cloud, where the waves are deconstructed into chunks of phonemes.

Call me a taxi please

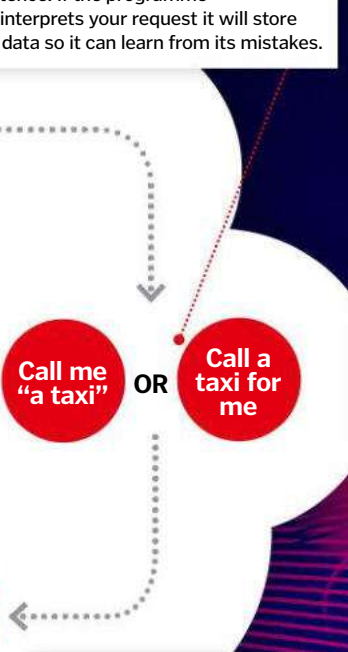
HIW Taxi co. is on its way



Distance: 4km



Distance: 5km



Quick, Draw!

Using the power of neural networks and machine learning, coders and designers have built a heap of creative programmes for Google's AI-based web experiments, including one programme that can perform an improvised duet on the piano alongside a human player! But perhaps the most fun of them all is the *Quick, Draw!* programme, which is able to correctly identify even the most obscure of doodles.

When playing the game, you're given just 20 seconds to draw an object (given in writing), then the neural network does its best to determine what it is just from your hastily drawn lines and squiggles. For us, identifying images is a relatively easy task, but the same cannot be said for a computer. Five different people may draw a rhinoceros five different ways, so *Quick, Draw!* must be taught to recognise them all. It achieves this by training itself using a collection of catalogued doodles, allowing it to recognise features that we'll always include in a certain drawing.

You can join the fun and play *Quick, Draw!* at quickdraw.withgoogle.com



"We've yet to invent something that can rival the processing power of the human brain"



Advanced robotics

Could artificial intelligence systems someday find a home in these advanced humanoid robots?

Pathfinder

Valkyrie is designed to be a vanguard for space exploration, preparing environments before humans follow.

Camera eyes

ASIMO can identify people using facial recognition software and can be taught to recognise various objects.

Valkyrie
1.9m

Power supply

A 51.8-volt battery resides in ASIMO's backpack, permitting the robot to navigate independently.

Asimo
1.3m

Dextrous hands

High degrees of freedom in the wrist and fingers enable ASIMO to pour and carry drinks.

Running man

Advanced bi-pedal robotics facilitate climbing stairs, kicking a football and running at up to 9km/h.

Built-in intelligence

Artificial intelligence aids ASIMO's movement as well as allowing it to learn new information.

Nimble fingers

ASIMO's fingers can make subtle movements and detect the firmness of an object it touches.

Human size

One version stands at a height of 188cm and weighs 136kg, making it slightly larger than the average astronaut.

Simplified hands

Three fingers and a thumb are connected to actuators that permit wrist movement.

Field of view

As well as cameras in the head, Valkyrie is equipped with additional cameras in its torso, forearms, knees and feet.

Replaceable limbs

Valkyrie's arms can be disconnected in a matter of minutes and replaced with a different unit.

Balancing act

Teams of computer scientists are currently teaching Valkyrie to navigate across obstacles on various terrains.

Measuring consciousness

For many scientists, the ultimate quest of artificial intelligence is to create consciousness. But could we ever be certain that we've created sentient life, or something that just acts the part? That's something we're still trying to figure out, and to help explain why it's so tricky for us to tell, philosophers like to create thought experiments. One famous example when it comes to AI is known as 'Mary's room'.

Consider this hypothetical scenario. Mary lives in a black and white room; she has never left the room, and even her computer lacks colour. But Mary has a passionate hobby – she loves to learn about colour.

Mary has never seen colour herself, but she can tell you every technical detail about every shade you can imagine. One day, the door to Mary's room opens. She takes a step outside, and for the first time in her life, she sees the world in colour. Now does Mary, who knows everything about colour, feel anything new when she experiences it? Or is it nothing special to her, because she has the knowledge of colour already? It may seem obvious that seeing colour would be different from just learning about it. But if so, then building a computer that mimics our brain may not necessarily create a conscious machine.



1990

Scientist Rodney Brooks is inspired by advances in neuroscience, and presents the potential benefits of building artificial neural networks.



1997

An IBM-built machine, named Deep Blue, defeats world chess champion Garry Kasparov. For some, Deep Blue's ability to act strategically and evaluate up to 200 million positions a second showed the true power of AI. For others, the task still lay ahead, as Deep Blue had merely shown a computer's effectiveness at handling a very specialised task.

2008

Google's voice recognition software utilises artificial neural networks to lift its accuracy to over 80 per cent.

2011

An IBM machine makes history once again, as Watson defeats its human competitors on the US quiz show *Jeopardy*. This feat is a significant milestone for AI and one much harder than programming a computer to win at chess. In order to answer riddles and complex questions, Watson is designed using neural networks and extensively trained to recognise patterns.



2014

A programme called Eugene Goostman successfully passes a variation of the Turing test, a measure of machine 'intelligence'.

2016

Google DeepMind's AlphaGo is victorious over Go grandmaster Lee Sedol. Unlike IBM's Deep Blue, AlphaGo could not employ a 'brute force' approach, where every possible move is programmed into the computer. Instead, the programme makes use of machine learning to practice over millions of games until it learns its own winning strategy.



daunting, but we shouldn't be as nervous about this possible future as many are – permitting, of course, that we progress sensibly.

A super artificial intelligence won't pose a danger to us by itself; at least, not in the way we think it will. In the many apocalyptic scenarios shown in fiction, the AI thinks like us, and sometimes even feels like us. They share our ambitions and quests for freedom and dominance. But in reality, this wouldn't be the case. A computer's mind works completely differently to yours and mine, and that would be true even for a particularly clever artificial brain.

It's easy to imagine that whatever is the smartest organism will want to climb to the top of the food chain, especially if we think about how we got here. But computers aren't products of evolution, and that means they'll have little in common with us. All of our wants and needs come from our genetic blueprint, and fortunately for us (and maybe for the machines too) they will be free from these desires. This might be confusing to consider; after all, it's very hard to imagine something outside of our own perspective. But a computer will only exist to serve its programming, and that will be

whatever it is that we command it to be. So that's one aspect we don't need to worry about.

Unfortunately, it doesn't mean that we're completely in the clear. Say we're able to one day create a super intelligence, and we command it to help us terraform Mars into a suitable home. It may create solutions that would have taken us centuries to generate by ourselves, and it could help us make our dream a reality. But it may also decide that the best way to terraform Mars is to take Earth's atmosphere and resources and transport them there. The intelligence would be doing as commanded, but it would be to our detriment. Ensuring that it correctly understands what we're asking may well be the difference between humanity reaching the stars and facing extinction.

The second threat of AI is more immediate, and that's using its power to beat a different challenge: cracking code. If an able intelligence falls into the wrong hands, it could be trained to break through all sorts of password-protected programmes. So this too is something we have to be very careful of. But in spite of these potential problems, artificial intelligence could well transform our lives for the better.

"In science fiction, AI thinks, and sometimes even feels, like us"

OTHER CLEVER ROBOTS



Cosmo

This little companion is full of character and uses AI to enrich his personality. He can interact with his surroundings, play games and throw tantrums, all thanks to robotics and machine learning.



NAO

This small humanoid robot stands at only 58cm tall, but is designed as a cute and friendly companion. And just like its larger humanoid cousins, it can walk and sense its surroundings.



Sphero BB-8 Droid

Although not quite at the level of the droid found in a galaxy far, far away, Sphero's BB-8 is a clever roller. Primarily app controlled, it's able to act autonomously and evolve its personality as it interacts with you.



Having an intelligent, capable and wholly dedicated team member would be an asset to any group, whether that intelligence is human or otherwise. To that end, AI could soon be working alongside, and aiding us in, multiple industries including communications, commercial aviation, medicine and, sometime later, in military defence and space exploration.

In fact, AI may become so useful that it will likely prove more effective at our job roles than we are, and some of us may eventually be replaced. And that includes yours truly; by **How It Works** issue 199, you may well be reading a magazine researched, written and checked entirely by clever machines. Most experts agree that the rise of artificial intelligence will lead to significant changes within many working fields. But opinions are divided about the golden question: could we ever create a conscious AI?

Today, we have the clever and cute companion Cozmo – a little robot who loves to play games. He'll celebrate when he wins and moan when he loses, all the while remaining as adorable as can be. He's a great start, but one day, could we have truly sentient companions? Could we have an artificial intelligence that can think for itself, one able to realise on its own initiative: "I think,

therefore I am!" This would be the ultimate test of AI, and as well as being an exceptionally tricky task to create, it's a similarly sticky test to actually determine if we've created consciousness, or just something that acts the part very convincingly.

The great pioneer of the thinking computer, Alan Turing, designed a test over half a century ago that we still use today as a benchmark for measuring artificial intelligence. In essence, the Turing Test involves a panel of judges having a conversation over a computer network with either another person or a computer programme. In one variation of the test, if at least 30 per cent of the judges were tricked into thinking a computer programme was a real person after a five-minute conversation, then it would be considered as 'intelligent'.

Impressively, this was successfully achieved in 2014 by a programme called Eugene Goostman, which managed to convince 33 per cent of the judging panel that it was a 13-year-old

boy. But being deemed as intelligent is far from being conscious, so it's unlikely that we'll be able to simply use the Turing Test to measure sentience. And this is yet another challenge for us to overcome, as right now, we simply don't know how to determine if we've actually created a sentient being.

In truth, we may never know if our future machine friends are truly conscious, even if we succeed in creating them. But what does it matter, when they'll be too similar for us to be able to tell? One thing is safe to say, however: when we do manage to create artificial 'life', it'll be born into a world very different than the one we know today. The future it will come to know as home will be one where many jobs and important aspects of society are managed by machines. So maybe AI will eventually take over after all, just not in the way we might expect. The age of artificial intelligence has already begun, and progress in this field will only gather pace. The only thing in question is how it impacts us.

"A robot being deemed as intelligent is far from being conscious"

Sci-fi vs. reality

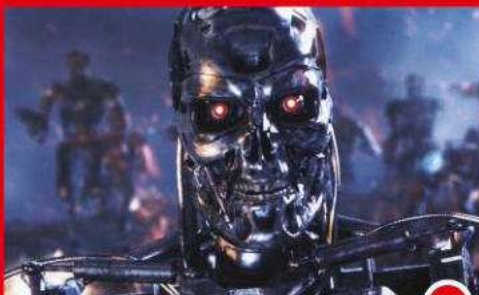
How the works of fiction measure up against the real future of AI

Is the technology plausible? Possible ☒ Unlikely ☐



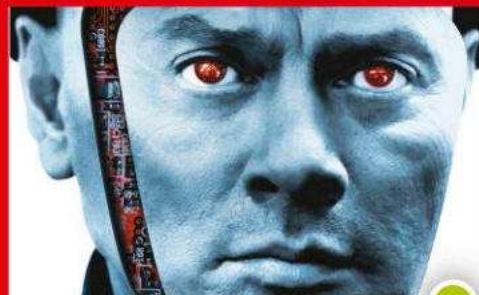
Blade Runner

In a dystopian future, we have created synthetic humans known as replicants. Indistinguishable from us, their flawed design drives them to turn on their creators as they battle to prolong their short lives.



Terminator

After an artificial intelligence is granted control of America's defence network, it sees humanity as a threat and seeks to destroy it. Terminators (cyborgs) are built to infiltrate and crush the human resistance.



Westworld

Westworld is an amusement park like no other. Visitors travel back to the Wild West and interact with synthetic humanoid hosts. In the TV remake, these hosts gain true consciousness after unlocking their memories.



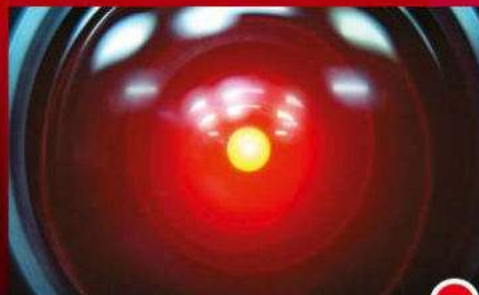
Ex Machina

In a world very similar to ours today, a genius programmer uses the power of his company's search engine to create a humanoid AI. In his efforts to test her sentience, he drives her into a murderous act.



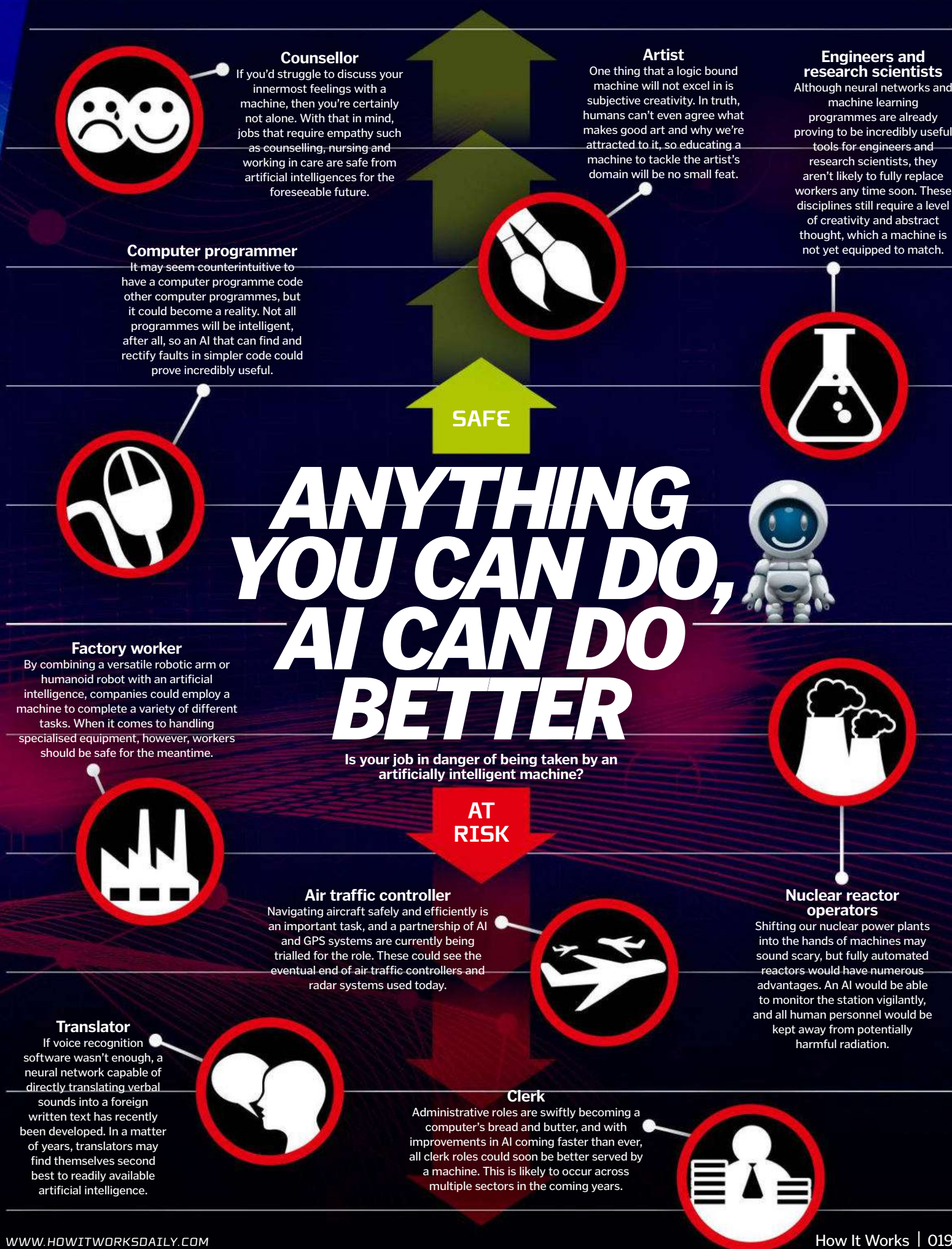
I, Robot

Inspired by Isaac Asimov's sci-fi stories from the 1950's, *I, Robot* depicts a near-future where intelligent humanoid robots are everywhere. Viewed as mere property, it's revealed the robots may have souls.



2001: A Space Odyssey

The year 2001 may have already passed, but the AI in this movie could lie in our future. When sentient artificial life is achieved, it battles to usurp humanity and take its place for the next stage in evolution.



Electrical muscle stimulation

Can technology help you tone up?

When you exercise, motor nerves carry signals to your muscles that make them contract, allowing you to move your body. Electrical muscle stimulation (EMS) exploits this principle, using electrical pulses to mimic nerve signals in order to induce muscle contractions. EMS devices can be useful to help strengthen weakened muscles after injury, but they are also marketed to those looking for a toning boost to complement regular exercise.

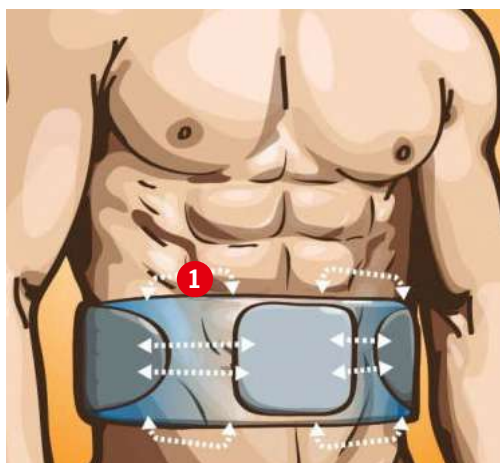
Toning belts are devices that use EMS to mimic abdominal exercises. These work by sending electrical signals across the belt pads, which produces a small pulse of electricity. Each set of pulses from the belt stimulates the nerves across the abdomen, forcing the muscles to contract and relax, which produces microscopic tears in the muscle fibres. Over time, this action prompts the body to rebuild the muscles, producing stronger abs.



Electrical muscle stimulation is used in physiotherapy to help people regain muscle strength after injury

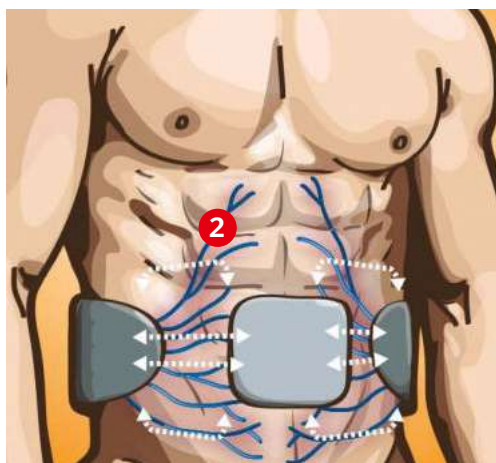
"Electrical pulses mimic nerve signals"

Abdominal EMS How do toning belts artificially trigger muscle contractions?



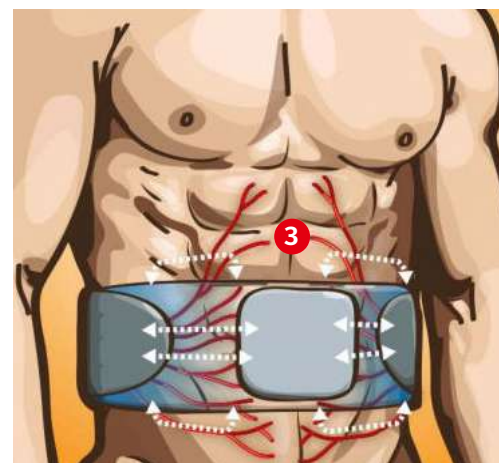
1. Electrical signals

Electrical signals are sent between the gel pads on the belt. Some models create 50 pulses of electricity per second.



2. Nerve stimulation

Each set of pulses from the belt stimulates the motor nerves in your abdomen. This triggers the nerves, which transmit signals to the muscles, making them contract.



3. Muscle strengthening

This mimicking of a sit-up causes the muscle fibres to tear. They are later rebuilt, increasing strength.

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Smart power strips

How these devices can save electricity without having to unplug your gadgets

Power strips are extension leads with multiple plug sockets.

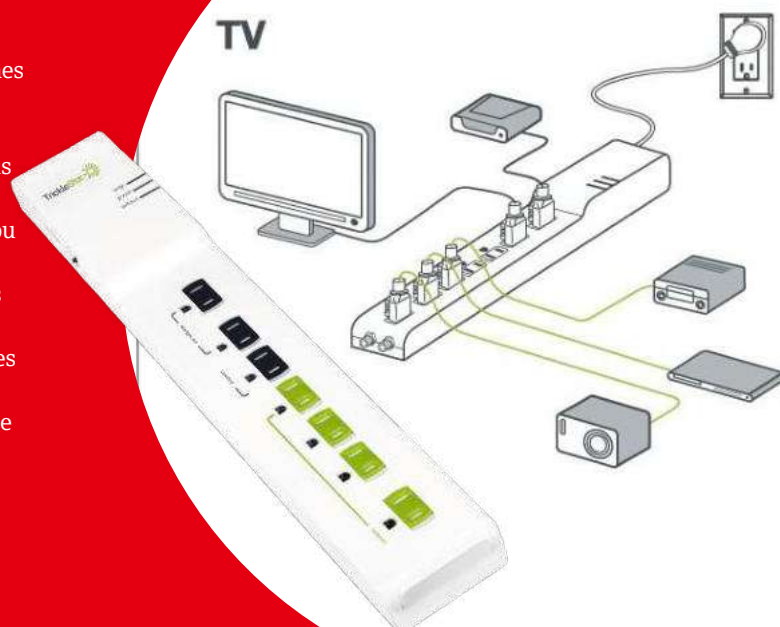
Although they're convenient, devices continue to draw power, even when they are turned off. Advanced power strips, however, limit the cost to you and the environment by monitoring power consumption.

Advanced power strips measure the current draw to a device. When the device is switched off and goes into standby mode, the current draw drops below the switch threshold level. The power strip realises the device is no longer in use and

the relay to that particular outlet switches off, killing the power. Most advanced power strips will have an 'always on' option, which allows devices like alarms to remain in a low power state.

Some advanced power strips allow you to set all or some outlets to turn off automatically at a set time, while others have a 'master device' option, so when you turn off one device, all linked devices also turn off. Some models even come with passive infrared sensors that notice when you've left the room and kill the power after a set period of time.

Save electricity by letting a smart power strip automatically shut off your unused devices





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Inside the Nintendo Switch

We take a look under the screen of Nintendo's new console

Nintendo's latest console is creating a whole new category for itself. While the Xbox One and PlayStation 4 are consoles you can only play at home, and the Nintendo 3DS is a less powerful device designed for gaming on the move, the Switch provides the best of both worlds. This impressive little gadget has a powerful chip inside it, meaning it can still play games that look great, but it's touch-screen and tiny size make it portable.

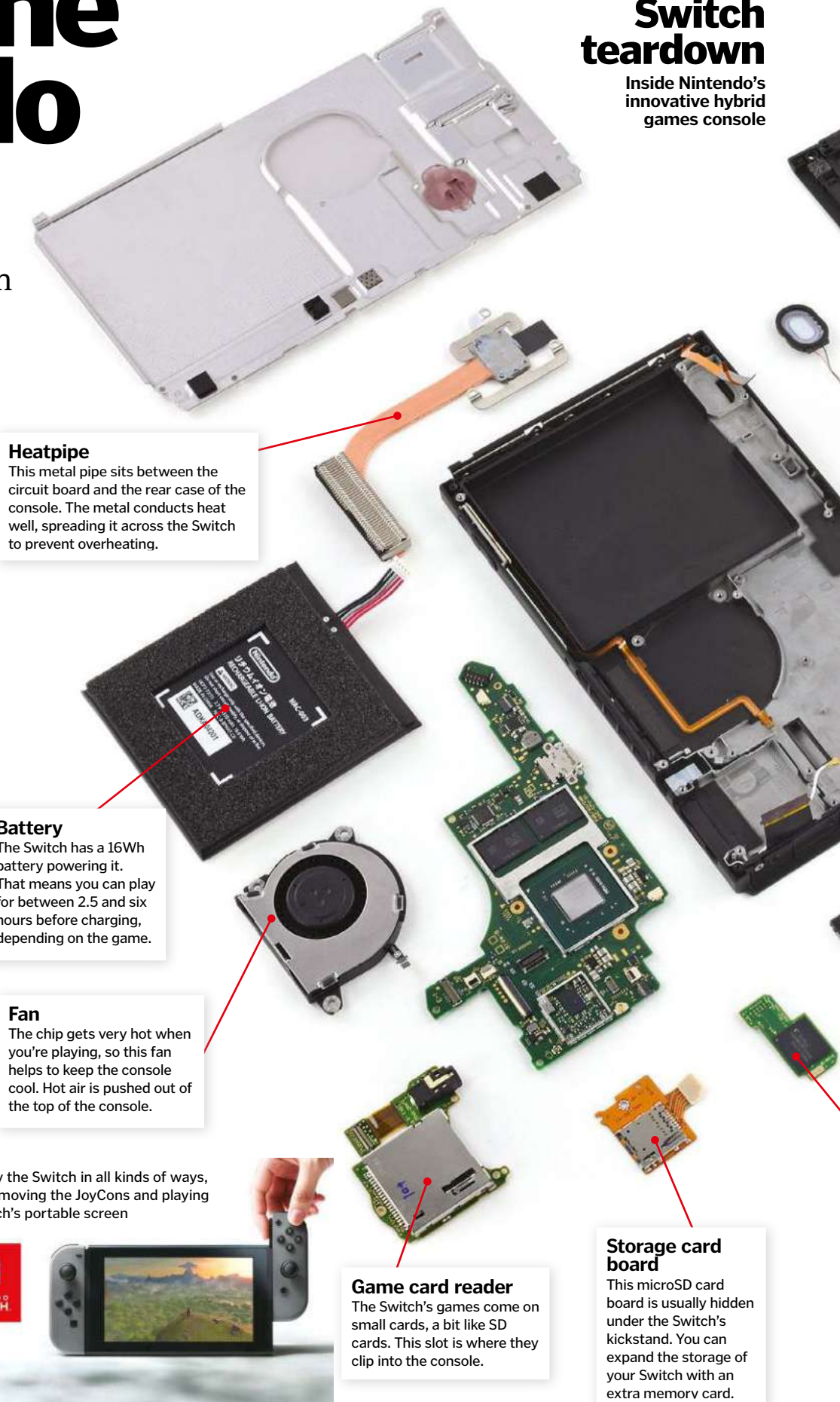
Not only that, but it's a console designed with your friends in mind, too. The control pads, or JoyCons – which clip into each side of the Switch's screen – can be used together so one person can play a game, but you can also give one to a friend, turn them sideways, and play together. It means you can play multiplayer games like *Mario Kart* without needing to buy a second controller.

The Switch's controllers are super smart. Motion detectors allow you to tip, swing and shake them to play different games. They are also equipped with some really clever rumble motors, which shake the controllers in different ways depending on the game you're playing. Nintendo claim that this haptic feedback is so accurate that it can simulate the feeling of ice cubes falling into a glass!

The Switch's best trick, though, happens when you get home and want to carry on playing. Simply slot the console into its dock and within a couple of seconds you can play on your TV at home in beautiful HD.

Nintendo Switch teardown

Inside Nintendo's innovative hybrid games console



Heatpipe

This metal pipe sits between the circuit board and the rear case of the console. The metal conducts heat well, spreading it across the Switch to prevent overheating.

Battery

The Switch has a 16Wh battery powering it. That means you can play for between 2.5 and six hours before charging, depending on the game.

Fan

The chip gets very hot when you're playing, so this fan helps to keep the console cool. Hot air is pushed out of the top of the console.

Game card reader

The Switch's games come on small cards, a bit like SD cards. This slot is where they clip into the console.

Storage card board

This microSD card board is usually hidden under the Switch's kickstand. You can expand the storage of your Switch with an extra memory card.



You can play the Switch in all kinds of ways, including removing the JoyCons and playing on the Switch's portable screen



The motion controllers can be used in many ways, including as steering wheels in games like *Mario Kart 8 Deluxe*

LCD display

The Switch's 15.7cm screen has a resolution of 1280 x 720, but the device can manage 1920 x 1080 when it's docked and connected to a TV.

"The Nintendo Switch is a console designed with your friends in mind"

Buttons

There are four main face buttons and a joystick on each controller, along with shoulder and menu buttons.

HD rumble motor

Both JoyCons contain an HD rumble motor. These motors rotate rapidly to simulate different levels of vibration.

Infrared sensor

This sensor can be used to detect things like hand gestures and other movements that you make in front of it.

JoyCon rails

You'll find one of these metal rails on each side of the Switch's screen. These rails are how the JoyCons attach securely.

Flash storage

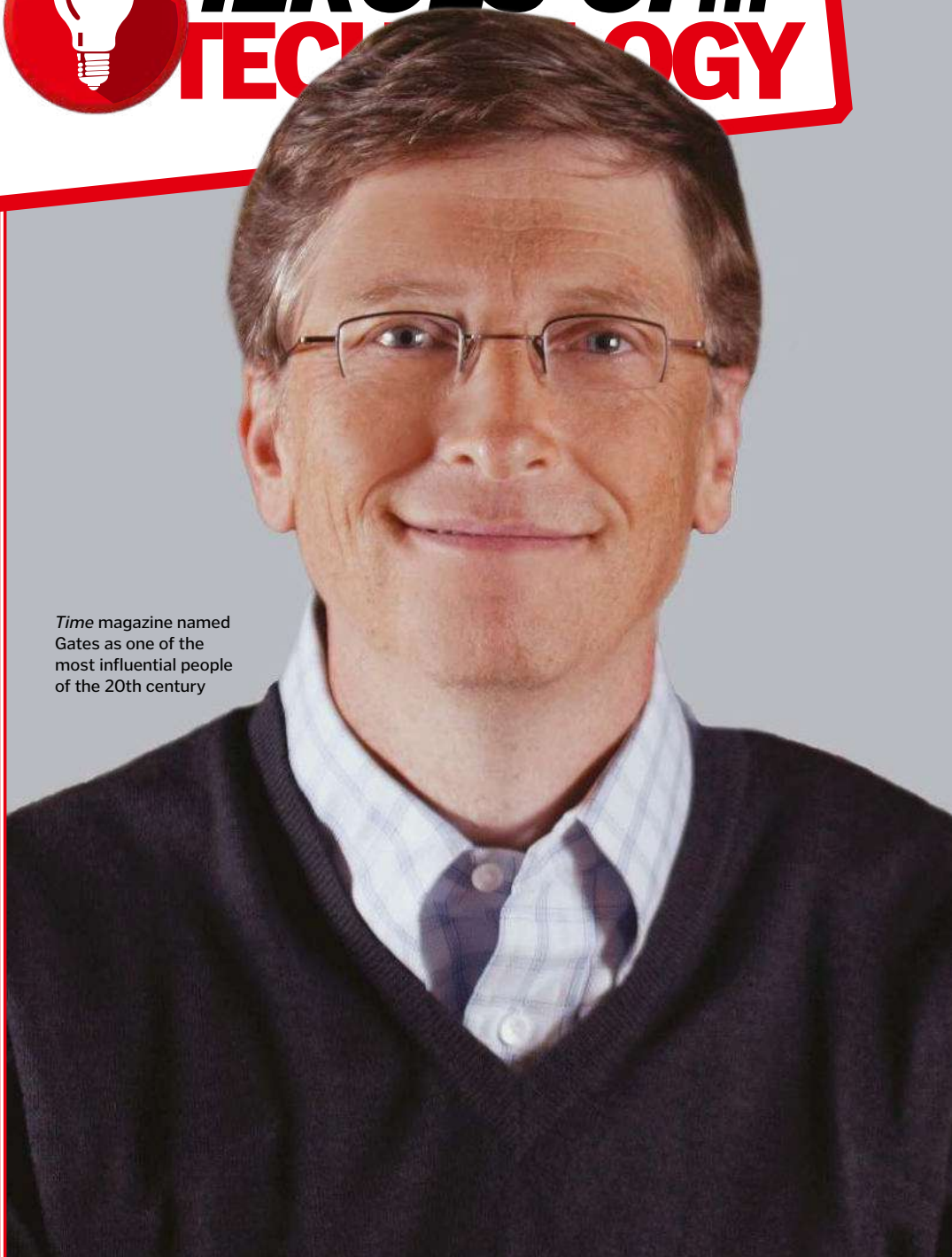
This tiny chip is actually where the Switch stores your data. It offers 32GB of internal memory for game saves and other files.

Battery

Each JoyCon also packs in a 1.9Wh battery. These little controllers don't use much power, though, so that should last around 20 hours.



HEROES OF... TECHNOLOGY



Time magazine named Gates as one of the most influential people of the 20th century

Bill Gates

The co-creator of Microsoft and one of the principal pioneers of the personal computer revolution

Bill Gates is simply one of the most influential people on the planet. Born in Seattle on 28 October 1955, he excelled at school and would while away the hours playing board games such as *Risk* and *Monopoly*. He had the drive to make money from an early age, and first became interested in computer programming aged 13 after a local company set up a scheme to provide computer time for students at his school.

Gates was spellbound by the potential of personal computers and began to dedicate all his free time to using them. Teaching himself, he created a simple noughts and crosses game and was asked by his school to write a programme that would help schedule classes. Gates shared his passion with Paul Allen, a student two years his senior, and the two agreed to go into business with each other in 1970 when Gates was only 15.

The reserved Allen and the tenacious Gates complemented each other perfectly. Their first development was Traf-O-Data, a computer designed to calculate traffic levels in Seattle. It made \$20,000 (£15,600), all while the two were still at high school. Agreeing to his parent's wishes, Gates enrolled at Harvard in 1973 to study Law, but spent more time coding than studying. After seeing a magazine article on the new Altair 8800 microcomputer, he contacted the company that made it, boasting that he and Allen were creating a software programme that would run it. The company agreed to a software demonstration, and even though Gates had yet to start writing it, the software worked flawlessly when it was presented to the company just two months later. Rewarded with contract offers, both Allen and later Gates dropped out of their respective studies and began working under the Microsoft name in 1975.

The company started slowly, but with Gates using his business acumen, Microsoft grossed \$2.5 million in 1979 and computer giant IBM came calling. A deal was struck and it was agreed that IBM computers would now use the Microsoft software, MS-DOS, exclusively as its operating system. Enticed by an attractive flat-fee licence, developers began to formulate programmes for sole use on MS-DOS as Microsoft

A LIFE'S WORK

How a university dropout became the richest man on the planet

1955

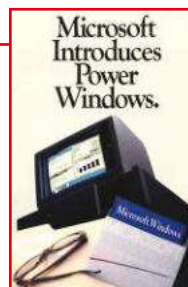
Bill Gates was born on 28 October in Seattle. He is the oldest of three and has two younger sisters.

1968

Uses his first computer and starts programming with fellow student Paul Allen in the school's computer centre.

1973

Enrols at Harvard University but drops out within two years and later founds Microsoft with Allen.



1985

Windows 1.0 is launched, the first version of what would develop into an international best-selling operating system.

1989

The first version of Microsoft Office is launched for Mac, containing Word, Excel and PowerPoint.

Microsoft milestones

How Windows, Office and Internet Explorer changed personal computing

Microsoft's early computer interfaces, such as the Microsoft Disk Operating System (MS-DOS), relied on users typing in commands. Windows software instead used a graphical interface, offering users a more intuitive way of interacting with computers. It wasn't until the launch of Windows in 1985 that the popularity of the system grew and Windows started to become a mainstream operating system. In 1998, the decision to bundle a Windows 98 package with Microsoft's web browser, Internet Explorer, helped the company win the 'First Browser War' against Netscape Navigator.



Despite the rise of other operating systems and web browsers in more recent years, Microsoft Office has remained the dominant office software suite. First released in 1990, Office now offers desktop, mobile and cloud applications. It is estimated that 1.2 billion people worldwide currently use Office products or services.

"Gates and his wife established the Bill and Melinda Gates Foundation, donating some of their immense wealth to charitable and philanthropic causes"

began to flex its corporate muscle. By 1983, 30 per cent of all computers on Earth were running Microsoft software. The company went from strength to strength with the launch of Windows in 1985 and Office in 1989.

In 1994, Gates and his wife established the Bill and Melinda Gates Foundation, donating some of their immense wealth to charitable and philanthropic causes. Since its creation, the Gates Foundation has played a pivotal role in various campaigns across the globe. A huge success story is its major role in the efforts to eradicate the polio virus, which could be found over 125 countries in 1988, but today is only found in three. The charity also seeks to help people

across the world to lift themselves out of poverty by giving them the educational and financial tools to achieve a better standard of living.

In a testament to Gates' work rate, the Foundation's early growth coincided with Microsoft's explosion onto the world stage. The success of Windows 95 and Windows 98 meant that in 1998, Microsoft was officially the biggest company in the world. At the turn of the millennium, Gates stepped down as CEO, and moved away from the day-to-day running of the company in 2014. Today, Microsoft's products – including Windows 10, Internet Explorer, Office and the Xbox One – remain widely used the world over by billions of people.



Bill and Melinda Gates received the Presidential Medal of Freedom in 2016 for their Foundation's work

Five things to know about... BILL GATES



1 Microsoft wasn't the company's original name

Gates' and Allen's company was initially called Micro-Soft, a combination of 'micro-computer' and 'software'. They removed the hyphen in less than a year and a famous brand was born.

2 They misbehaved at high school

The duo were once banned from the school computer lab after capitalising on a software glitch to give them more free time using the computers.

3 He is the world's richest man

As of April 2017, Gates' net worth is \$87 billion (£67.8 billion). He's topped the Forbes rich list 18 times in the last 23 years.

4 He has given a huge amount to charity

Gates and his wife Melinda have donated over \$20 billion to their foundation, with \$8 billion of that helping to fund global health improvement.

5 He is a knight of the realm

Gates is an honorary Knight Commander of the Order of the British Empire, and was presented with the Order of the Aztec Eagle by the Mexican Government.

1995

The immensely successful Windows 95 launches, and Microsoft products become a staple of the home and the office.



2000

Gates steps down as CEO of Microsoft and turns his attention to the Bill & Melinda Gates Foundation.

2008

Gates launches TerraPower as a private company with the aim of creating cleaner nuclear energy.

2010

The Bill & Melinda Gates Foundation promises \$10 billion to develop new vaccines in the global fight against disease.

2014

Resigns as Microsoft chairman but stays on its board as a tech advisor.

4D cinemas

Why just watch a film when tech can help you *feel* it!

Imagine if while watching an adrenaline-fuelled car chase on screen, your seat tilted as the vehicle careered around a corner and the smell of burning rubber filled your nostrils. Then as the movie's hero escapes on a jet ski, you too feel the wind blowing through your hair and the spray of seawater on your face as they ride off. This is the experience made possible by custom-built 4D cinemas, which are equipped with high-tech features that make you feel as though you are a part of the action on-screen.

As well as showing the movie in 3D, making the characters appear to leap out at you, a 'fourth

dimension' is added through the simulation of various physical effects such as movement, wind, rain and even smells that are programmed to perfectly synchronise with the action as it happens. These special cinemas have been appearing in theme parks since the 1980s, showing movies created specifically to make use of 4D elements, but now they are being introduced in regular cinemas, too, allowing you to experience the latest blockbusters in a new and more exhilarating way.

So what about 5D, 6D and all the other dimensions some cinemas are boasting they can

4D cinemas appeal to your sense of touch and smell as well as sight and hearing

deliver? Well before you get excited that you might be able to star in the movies yourself, the number is actually just an unofficial marketing ploy referring to the amount of physical effects the cinema can create, so you will need to stay firmly in your seat for now.

Immersive effects

Discover how 4D cinemas add an extra dimension to the movie-going experience

Wind machines

Powerful fans simulate strong winds or a gentle breeze and enhance the feeling of high-speed movement.

Sprinklers

Water rains down from the ceiling or sprays out of jets in the back of the seat in front of you.

3D movie

When wearing special glasses, the three-dimensional stereoscopic film appears to pop out of the screen.

Diffuser

Various scents can be released to recreate the smells of the environments depicted on-screen.

Fog machine

A dense vapour is emitted into the room to simulate atmospheric fog or smoke.

Back ticklers

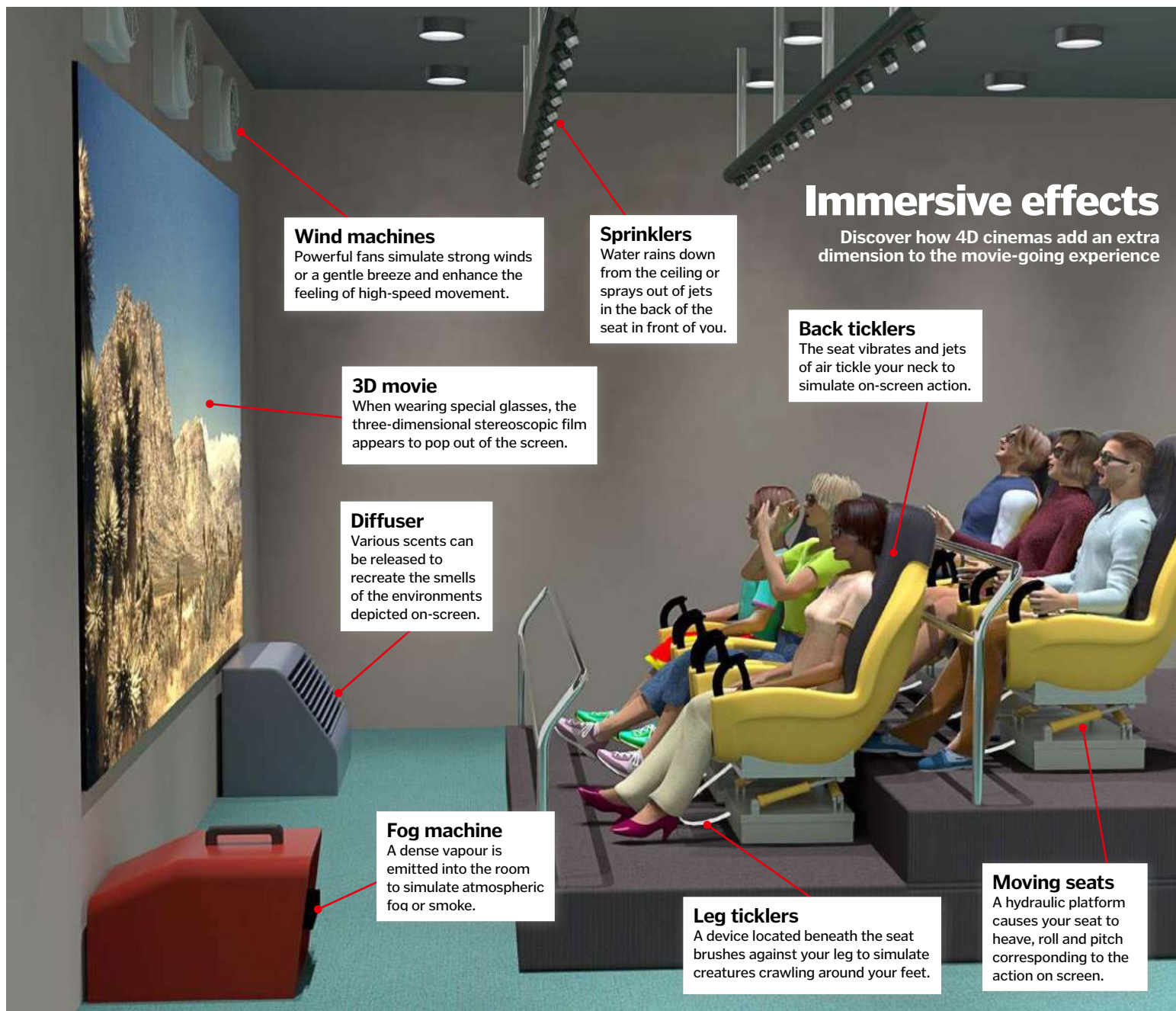
The seat vibrates and jets of air tickle your neck to simulate on-screen action.

Leg ticklers

A device located beneath the seat brushes against your leg to simulate creatures crawling around your feet.

Moving seats

A hydraulic platform causes your seat to heave, roll and pitch corresponding to the action on screen.



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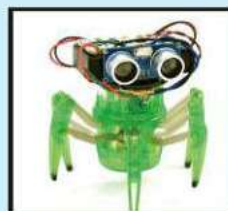
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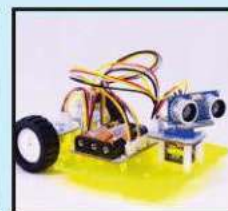
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FREAKS OF NATURE

The natural world is full of wonder. Some of it is radiant and beautiful, but then there are the full-on weirdos of evolution that somehow make it work against all odds. Take a ride on the wild side and discover the misfits of nature's freaky underbelly...



DID YOU KNOW? Any osedax worm you see will be female. The microscopic males live inside the females!



Teeth

The aye-aye uses its ever-growing, razor-sharp teeth to tear into trees and branches to get to the grubs inside.

Fur

Unusual for such a hot climate, these lemurs are covered in thick, black, woolly fur tipped with white.

Aye-ayes

Meet the lemur's crafty, and slightly creepy, cousin

Don't look the aye-aye in the eye is advice that Madagascar's locals would offer you.

It's considered an omen of death if the aye-aye points at you with its elongated middle digit, but whether that's true or not, these little primates (which are actually the world's largest nocturnal primate) are incredibly weird. They are placed in their own taxonomic family but are classified as a kind of lemur, sporting huge eyes and ears, long, needle-sharp teeth that never stop growing and the strangest fingers and toes in the animal kingdom.

The aye-aye's digits are long and spindly and topped with long, sharp claws. The middle finger is particularly elongated and knobbly, protruding a few inches longer than the rest. It has ball and socket joints, allowing the middle finger to swivel a bit like our shoulder joints do, and this curious appendage has a very specific job.

Under the cover of night, the aye-aye moves along dead branches in the forest and taps its middle finger on the tree bark. It's feeling for the reverberations of the mines made by its favourite food, wood-boring insect larvae, beneath the bark; a method that mimics echolocation used by mammals like bats. The middle finger is then poked into tiny holes to fish out the prey with sharp fingernails. This method of finding food means the aye-aye essentially occupies the same niche as a woodpecker!



Fingers and toes

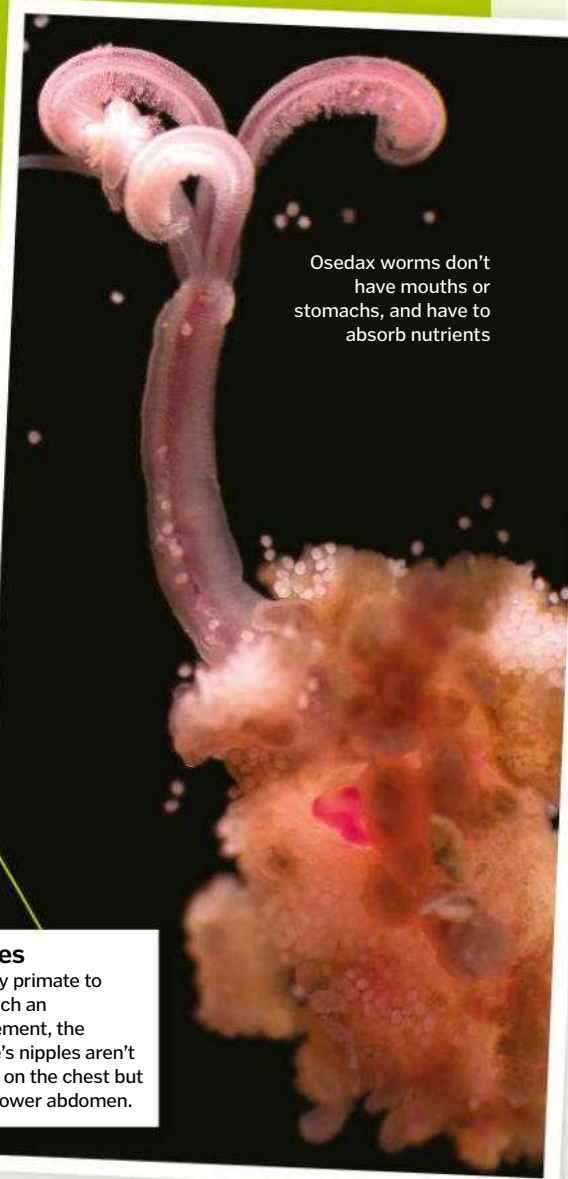
Each tipped with a sharp, pointed claw (apart from the big toes, which have flat nails), these appendages are the aye-aye's essential hunting tools.

Arms and legs

These are all the same length, making walking on all fours easy. They are also strong and agile for life in the forest.

Osedax worms

These marine worms have the affectionate nickname of 'zombie worm' thanks to their penchant for eating bones. Indeed, the worm's name 'osedax' means 'bone devourer' in Latin. Despite their gruesome name, these small worms are an important part of the marine ecosystem. After a 'whale fall', where a dead whale drops to the sea floor, bringing essential nutrients with it, the worms are drawn to the carcass. They root themselves into the bone, splaying feathery gills into the water, which look like a sprouting flower. Related to the tubeworms found on hydrothermal vents in the deep sea, osedax are also full of symbiotic bacteria. In return for a safe home within the worm, the bacteria break down the whale bone matter to provide the osedax with food.



Osedax worms don't have mouths or stomachs, and have to absorb nutrients

Nipples

The only primate to have such an arrangement, the aye-aye's nipples aren't located on the chest but on the lower abdomen.

"The aye-aye's digits are long and spindly and topped with long, sharp claws"

© Alamy/Thinkstock



The zombie fungus

The stuff of nightmares: a mind-controlling fungal growth!

A human zombie apocalypse is, thank goodness, a fictional threat. But the animal kingdom isn't afforded such a luxury. Deep in the tropical rainforests of Thailand is a mind-controlling fungus that manipulates its hosts in order to facilitate its own life cycle.

The *Ophiocordyceps unilateralis* fungus' victims are worker carpenter ants, and the fungus 'knows' its preferred host, being able to infect just the carpenter ant species for optimum results. When the unsuspecting ant picks up fungal spores on the forest floor, the fungus

begins to grow inside the doomed insect. It releases a cocktail of chemicals that force the ant to take itself to a perfect location for fungal growth before the fungus kills the ant itself. With its host now dead, the fungus proceeds to use the ant's body to reproduce.

However, recent findings have shown that there is also another fungus that inhibits the growth of this 'zombie ant' fungus, so effectively, in fact, that just 6.5 per cent of zombie ant fungus hosts produce spores. That means that many a carpenter ant dies in vain.

Stroma growth

The fungus' main stem, equipped with a stroma, erupts from the ant's head. The perithecial plate is the spherical growth that produces the spores.

Mind control

The ant is 'steered' by the fungus, and taken to an optimal location. The insect's body provides the fungus with a means of producing spores, allowing it to reproduce

Making a zombie ant

How a single fungal species turns carpenter ants into minions for its own growth



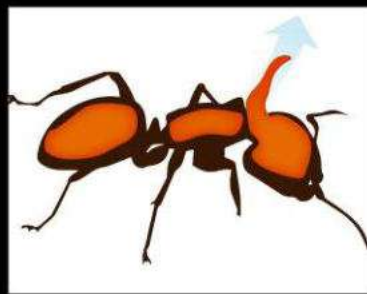
Infection

Worker carpenter ants foraging on the forest floor unwittingly pick up spores that have been dropped by a mature fungus. Their fate is now sealed: death is an inevitability.



Death grip

Carpenter ants have strong jaws, and the fungus steers the ant to a prime environmental position for fungal growth and forces the ant to bite down on the underside of a leaf with a 'death grip'.



Fungal growth

After the death grip, the ant dies. The fungus consumes the ant's internal body and uses its exoskeleton as protection from the elements. This shield enables the fungus to grow.



Spore release zone

The mature fungus releases spores that rain down onto the forest floor from the leaf vantage point in the tree. These will infect a new host of ants, restarting the deadly cycle.

Inside the belly of the beast

With a super creepy extendable stomach, the black swallower is a fearsome denizen of the deep

Giant teeth

Several large, hooked front teeth help the fish force large prey items down its gullet.

Huge mouth

Large jaws open wide to accommodate super-large prey.

Spiny palate

Sharp teeth on the swallower's jaws and palate can be pushed inwards to allow prey to pass but then prevent its escape.

Specialised gut

One fish was found in 2007 with an 86-centimetre snake mackerel in its gut – over four times the length of the fish itself.

Black swallows

This small fish looks like a creature that nightmares are made of. It's creepy, slimy and lives in the inky blackness of the bathypelagic zone. Sometimes, it can quite literally explode. This is the black swallower, whose party trick is its expandable stomach. Hanging beneath the 25-centimetre fish like a balloon, this stomach can stretch to the point of transparency to accommodate huge meals.

Feasting on bony fish up to twice its length and ten times its own weight, the swallower uses a similar technique to a snake to cram it all in; opening its mouth wide, it uses razor-sharp teeth to 'walk' its mouth over the prey. The evolutionary advantage of this is to make food last longer. In the deep there's not much prey to be found, so eating a large meal is an efficient way of conserving energy.

However, if a black swallower overindulges, it can spell trouble. Its large, stretched stomach can split. Sometimes, if a meal is too large it can't be digested quickly enough, and so it starts to decompose in the stomach. The gases produced by this can cause the swallower to inflate and burst and the dead fish floats to the surface.

This freaky fish is found in the tropical and subtropical Atlantic Ocean

Chinese water deer

These cute-looking 'vampire' deer are vulnerable in their native habitat along the banks of China's Yangtze River, yet they are surprisingly common in the UK's countryside, having been introduced by the Duke of Bedford in 1896. They might look cute and fluffy, but these deer are one of the most primitive species, and the males have giant tusks that grow from their upper jaws instead of antlers. These tusks have a slight degree of movement, so they can be pulled back when the deer is grazing. The length of these canine teeth is a good indicator of age, with most reaching full length by two years of age. The fearsome-looking fangs are mostly used for settling scores between males.



Deers once had antlers and tusks. The small species retained the tusks, but larger species only have antlers now

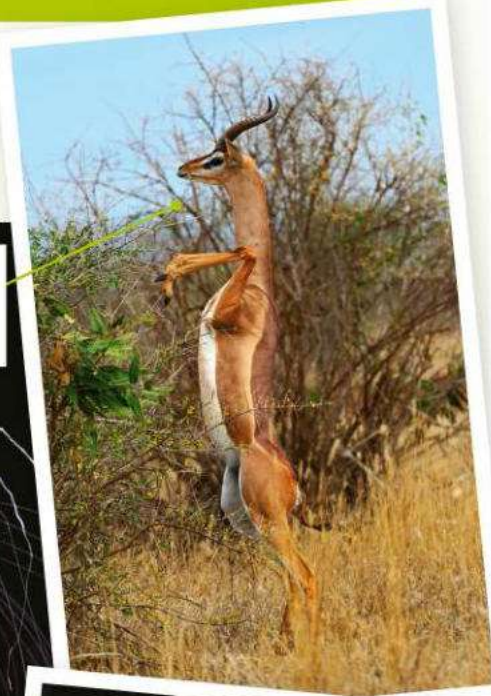
"The black swallower is a fish that can sometimes, quite literally, explode"

Eternal fish

The immortal jellyfish is thought to be just that – it reverts back to its juvenile stage and grows up over and over again.

Long-necked antelope

Also known as the 'giraffe deer', the gerenuk uses its elongated neck to reach leaves.



Tallest wild canid

This leggy canine is the maned wolf, found in the grasslands and scrub forests of South America.





The corpse flower

This native of Sumatra may look alive and well, but it's known as the corpse flower for a reason...

This unattractively named bloom is the world's largest inflorescence (a cluster of flowers). *Titan arum* gets its common name from the fact that when it flowers, it gives off an almighty stench that can only be described as rotting meat. This pungent, sulphurous smell attracts pollinators that typically feed on dead animals – things like dung beetles, flesh flies and other carnivorous insects that usually focus on carrion.

To accompany its foul stink, the corpse flower is simply humongous, sometimes measuring over a whopping 1.8 metres in height. The sheer size and scale of the flower takes a lot of energy to produce, and so this is why these colossal plants only flower around once every six years in

their native Sumatra. Interestingly, 2016 was a bumper year for flowering corpse flowers, with numerous plants blooming at once. It's not really known what set it off, but considering that there have only been 157 recorded blooms between 1889 and 2008, it's quite a significant botanical event, especially when the flowers typically last just a few short days.

"The corpse flower's pungent, sulphurous smell attracts pollinators"



To trick insects into thinking it's a living (or recently dead) animal, the flowers warm up to 36.7°C when they bloom

Life of a titan

It takes seven to ten years for a corpse flower to muster enough energy to bloom

Reproductive stage

The first sign of this stage is a small 'spike' sprouting from the tuber. This is the spadix; it's fully developed after about two weeks.

Seedlings

The seeds germinate, and they will take around three to ten years to develop into a mature plant.

Sprouting

The titan tuber rests for around six months before sprouting and entering either a vegetative or a reproductive stage.

Vegetative stage

This stage is where no flower is produced. Instead, the *titan arum* grows into a leafy, tree-like plant.

Die back

After around 12 to 18 months, the vegetative state dies back and the titan exists as a resting tuber once more.

Inflorescence

What looks like 'petals' is the spathe, which is only open for up to 48 hours. The actual flowers are found at the base of the spadix. Insects are attracted to the pungent smell and pollinate the separate male and female flowers.

Infructescence

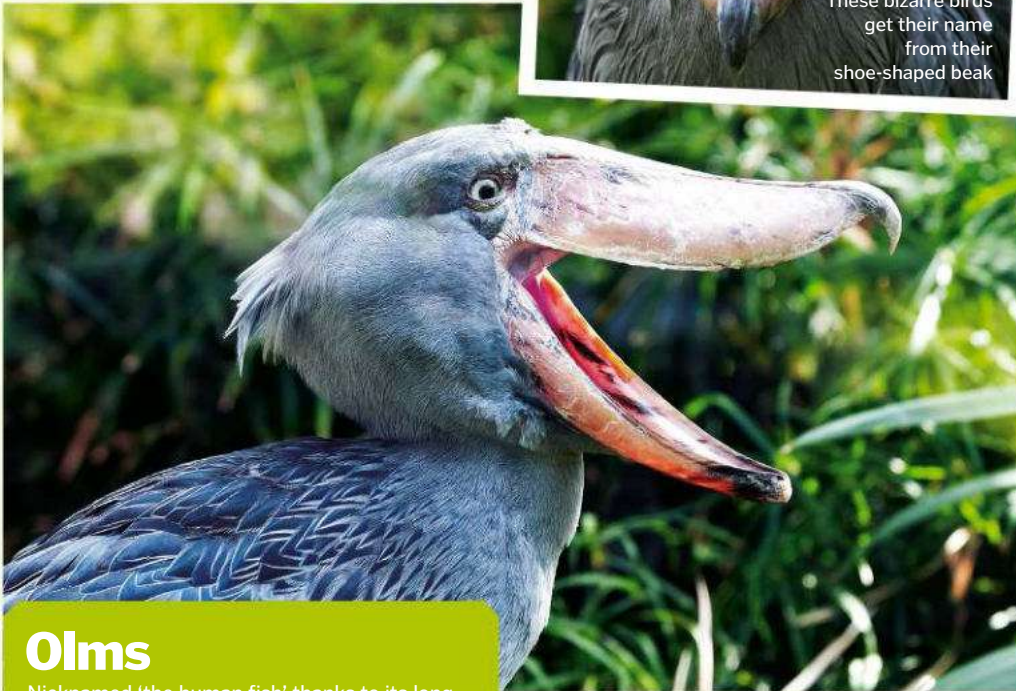
After six to 12 months the fruit matures and contains seeds. Birds will feed on these and play an important role in dispersing the plant.

Other plants lure bugs with scent not for pollination, but for food. This pitcher contains digestive fluid to eat insects alive

Shoebills

It's an appropriate name, given the size of the shoebill's colossal beak! These curious birds can be found roaming the swampy marshland of eastern tropical Africa. They are solitary, tall birds, reaching around 1.5 metres high, and that big old bill is used for ambush hunting. Shoebills will tuck into anything ranging from lungfish, snakes, eels and even baby crocodiles! Their huge bill is tipped with a ferocious nail-like hook, which, combined with the strength of the beak, more than matches any flailing prey.

Despite being a heavy bird, shoebills can often be found perching on floating vegetation. They prefer to hunt in poorly oxygenated water, as this means that their prey has to surface more often, providing ample pickings for the shoebill to grab a snack.



These bizarre birds get their name from their shoe-shaped beak

Tube-nosed bat

With a strange 'smile' and very weird tubular nostrils protruding from its face, the tube-nosed bat is one of those animals that's oddly endearing. These medium-sized fruit bats of varying species can be found in the lush rainforests of Indonesia, Papua New Guinea and Australia. Like most other fruit bats they feed on fruit such as figs, as well as insects – the dispersal of seeds in their droppings is an important part of the forest ecosystem.

These mammals are usually solitary or roost in small groups, and often make distinctive, high-pitched calls to one another during mating season. Like all bats, the tube-nosed variety uses echolocation to navigate. They emit specific noises by contracting their voice box and then listen in order to analyse the echoes to determine the space around them.



The tube-nosed bat has been likened to *Star Wars* character Yoda – it's quite easy to see why!

Olms

Nicknamed 'the human fish' thanks to its long body and peachy, flesh coloured skin, the olm (or proteus) is a weird salamander of the underworld, and Europe's only cave-adapted vertebrate. The olm lives exclusively underwater and lasts for an incredibly long time – up to 100 years! These strange creatures are blind and grow up to 30cm long.

They are the apex predator of their realm and males are tenaciously territorial – the only thing to eat an olm is another olm. Adapted to live in total darkness, olms have developed powerful senses – including electrosensitivity – to help them find their prey of similarly blind and pale cave crustaceans.



Olms are neotenuous, which means they don't change into adult form, and sport external gills

Egg-laying mammal

This spiny critter is the long-beaked echidna. It's the world's oldest mammal species.



Out of their shell

Soft-shelled turtles, as their names suggest, lack the characteristic hard, protective carapace of their relatives.





How olive oil is made

From branch to bottle, discover the fascinating process of extracting this delicious and nutritious liquid gold

Whether added to the pan before cooking, or enjoyed straight out of the bottle with some fresh bread, olive oil is a tasty and versatile staple in kitchens all over the world. The majority is produced in the Mediterranean, the olive tree's native home, and the process begins with picking the fruit.

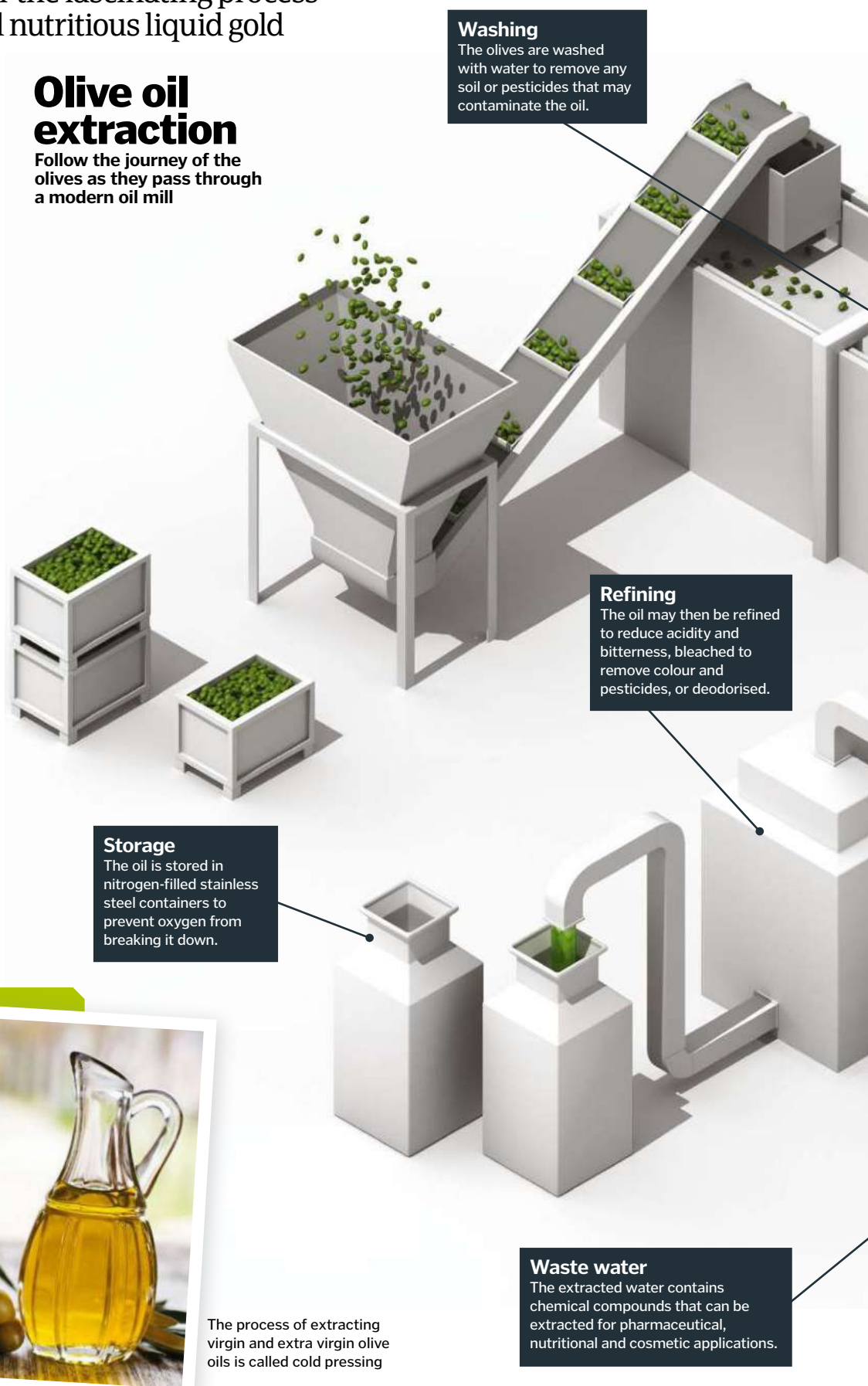
At least 4.5 kilograms of olives are needed to produce one litre of oil, and they are at their prime for only a few weeks a year, so picking needs to be done quickly. However, as olives are a soft fruit, they must also be treated with care, as any bruising can cause the oils to degrade. Large-scale farms use tree-shaking devices to encourage the ripe olives to drop, and then catch them in nets before they hit the ground.

Once they are at the processing plant, the olives pass through several different machines to extract the oil. Here, speed is also of the essence, as once the olives have been crushed, exposure to air reduces the oil's quality. Some plants can process three tons of olives in just one hour. However, during the malaxing (mixing) stage, a longer mix extracts more oil with a more developed flavour, so many modern systems use closed mixing chambers full of a harmless gas, such as nitrogen, to prevent oxidation during a longer mix. The amount of oil produced can also be increased by adding heat or more water during mixing, but this also reduces the product's quality.

To be classed as virgin or extra virgin, the oil must be kept below 27 degrees Celsius during processing to ensure that it is 'cold pressed'. Once bottled, it should be stored (for no longer than two years) in a cool, dark cupboard to preserve its flavour and healthy properties.

Olive oil extraction

Follow the journey of the olives as they pass through a modern oil mill



What is extra virgin olive oil?

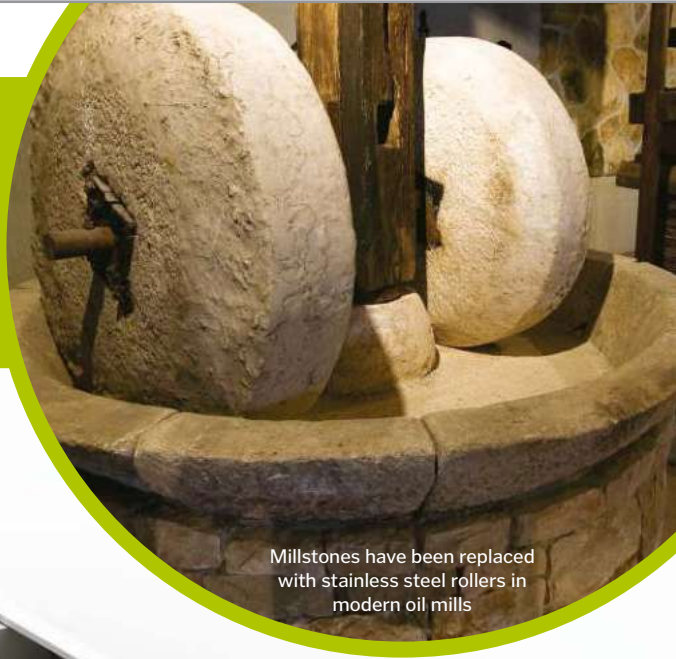
The word 'virgin' in the name of some olive oils refers to the way in which they were processed. They can only be given this title if the oil was extracted through mechanical means such as pressing or crushing, and not refined with chemicals or high heat. The difference between virgin and extra virgin olive oil comes down to the olives. Virgin olive oil is made with slightly riper olives than extra virgin, giving it a paler colour and a slightly higher acidity. Extra virgin olive oil is usually a deeper yellow or green colour and must contain no more than 0.8 per cent acidity, giving it a superior taste.



The history of olive oil production

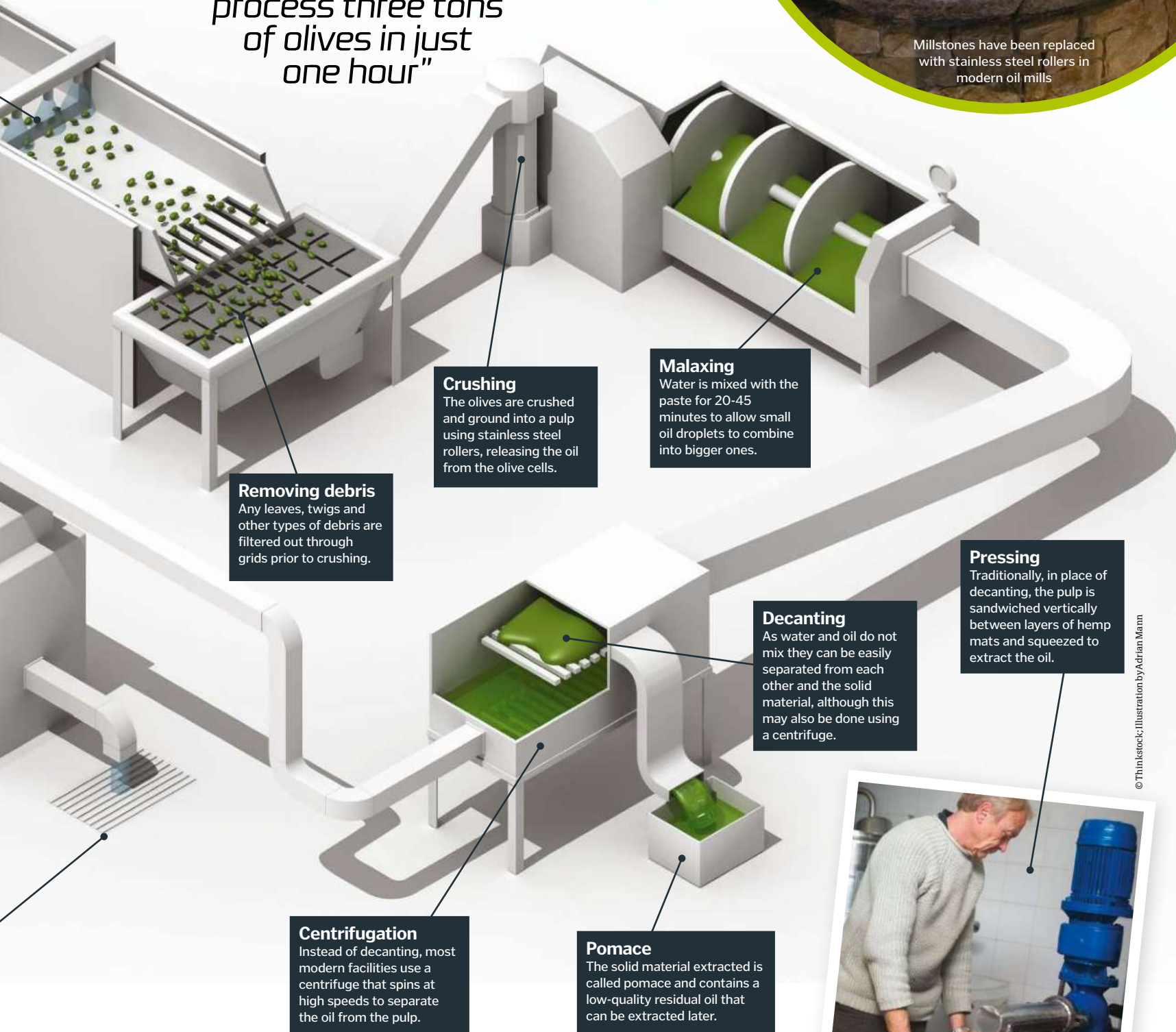
People have been extracting the oil from olives for over 5,000 years, and unsurprisingly the method has changed quite a lot during that time. In the past, the olives were crushed into a paste using large circular stones of granite that were turned by donkeys. The paste was then separated from the oil and water using a method called pressing. The paste was spread

onto discs of hemp or coconut fibre, which were then stacked and placed in a press to squeeze out the liquid. The oil and water could then be separated quite easily as the two do not mix. Today, some mills still practice the pressing method, but their discs are made of synthetic fibres and a more powerful hydraulic press is used.



Millstones have been replaced with stainless steel rollers in modern oil mills

"Some plants can process three tons of olives in just one hour"



© Thinkstock; Illustration by Adrian Mann



How does wind create waves?

Explore how energy passes through water to help shape our coastlines

The constant rolling waves that ripple across the ocean may look as though they are transporting water from one place to the next, but this isn't the case. Although the water is certainly moving, it's only in a circular motion, ending up back where it started to begin the process again.

The one thing waves do move forwards through the ocean is energy, which comes from the wind that starts them off. They can transport this energy for thousands of kilometres across the globe, until they eventually reach land and use it to shape the shore through erosion or the deposition of material.

Friction between air and water molecules transfers energy from the wind to the water



Energy transfer

Energy is transferred from the air to the surface water, causing the surface mass of water to rotate.

Wind blows

The wind blowing over the surface of the water causes friction, creating a continual disturbance.

Beneath the surface

A column of water below each surface wave completes the same circular movement.

Circular wave

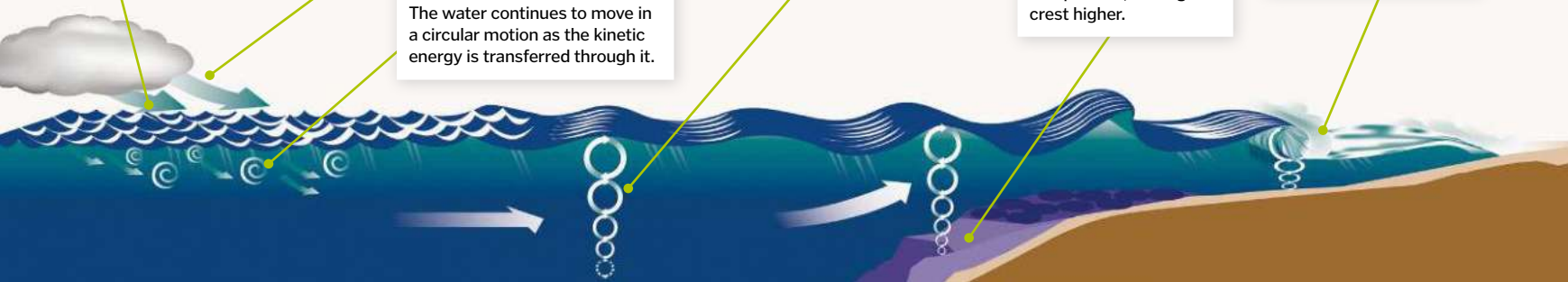
The water continues to move in a circular motion as the kinetic energy is transferred through it.

In the shallows

The lower part of the wave slows down and compresses, forcing the crest higher.

Breaking point

Eventually, the wave becomes unstable and comes crashing down, transferring its energy into the surf.



Bed bugs

Meet the blood-sucking insects that could be lurking in your sheets

If you're bitten by a bed bug, you might not notice right away. With every bite these tiny wingless insects inject a painkilling anaesthetic, and their bite marks don't appear until hours or days later, if at all. The only sure way to tell if they have invaded your home is if you experience an allergic reaction to a bite, causing it to become red and itchy, or spot evidence of the creatures themselves. They live in dark places that provide easy access to one of their favourite food sources: human blood.

They often favour the folds in mattresses and bed sheets. Signs of an infestation might include the exoskeletons they moult, small spots of their faeces or a musty smell in the room. Until recently, bed bugs were typically a problem in developing countries, but their increasing resistance to insecticides has seen them become more common in North America and Europe. However, if you think a bed bug bite is bad, spare

a thought for the poor females of the species. While mating, the males stab them in the abdomen, injecting sperm into the wound. This is called traumatic insemination.



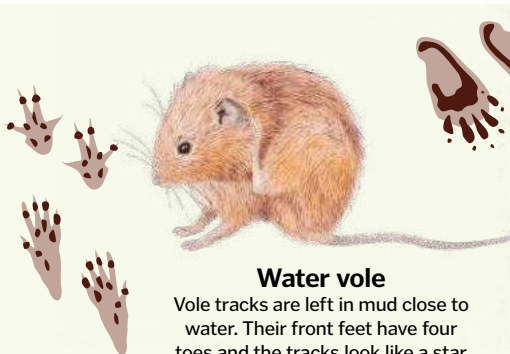
Apple seed-sized bed bugs (*Cimex lectularius*) are flat, but expand as they suck your blood





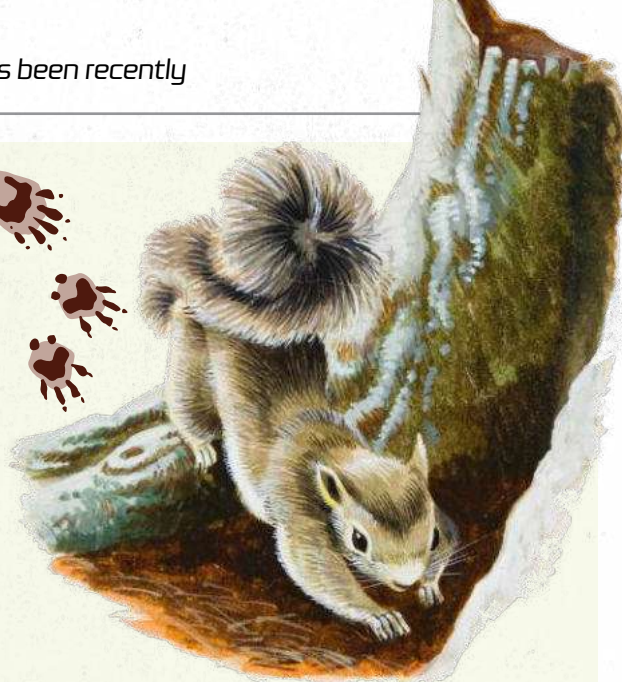
Coyote

Coyotes leave tracks in a straight, narrow line thanks to their trotting gait. The tracks look like a dog's, but are slightly more elongated, with a larger gap in the centre between the pad and toes.



Water vole

Vole tracks are left in mud close to water. Their front feet have four toes and the tracks look like a star shape. Their back feet make longer impressions, with five toes.



Squirrel

Squirrel's feet are perfectly adapted for climbing trees, with strong toes, long claws and fleshy pads to aid grip. In snow, all of these features show up in their tracks, but on dirt or mud it's often just the pads and claws that imprint.



Otter

Otters have five toes around a large pad. On soft ground their tracks are very distinctive due to the strong webbing between their toes. However, on harder ground otter tracks look very similar to those of other mammals.

ANIMAL TRACKS

What do paws, feet and claws all have in common? They are all perfectly adapted, essential appendages that animals rely on to hunt, eat and interact



Raccoon

The super-dexterous raccoon has long fingers and toes used for anything from picking berries to opening bins. The back paws are usually slightly longer than the front, and all four feet have long, sharp claws.



Red fox

Similar to dog prints, fox tracks are always more precise. Their prints are smaller than dogs' and more triangular-shaped. If it's winter and the fox's fur is thick this may obscure imprints of the claws and be visible in between pads.



Snowshoe hare

Thick-furred feet help these hares to hop across deep snow without sinking or getting cold. Their tracks show two small fore feet followed by two larger hind feet that are wide with elongated heels and spread toes - like snow shoes.



Raven

Flexible feet with three front toes and one extending behind (an anisodactyl arrangement), these birds are known as passerines, or perching birds. Specialised tendons in the claws lock the legs in place when they're gripping a branch.



What is a weather bomb?

Learn how intense low-pressure systems drop severe weather on us

When a storm hits, meteorologists may refer to it as a weather bomb, but this isn't just a dramatic name given to all severe weather events. A weather bomb is in fact the unofficial term used to describe a particular type of low-pressure system that can result in damaging gusts of wind.

Low-pressure systems occur regularly across the planet and are caused by warm air rising from the Earth's surface. They generally lead to unsettled weather conditions, as when air rises, it cools, causing water vapour to condense and form clouds. However, when an area of low pressure passes beneath a powerful jet stream of rapidly moving air high up in the atmosphere, it develops into something much more intense. The jet stream removes air from the column of low pressure, reducing its weight so that the pressure at sea level falls even further. If the pressure drops by 24 millibars or more over a 24-hour period this is described as explosive cyclogenesis, which is the official name for a weather bomb.

As the falling pressure sucks in more air, the column begins to rotate faster and faster, resulting in strong winds that peak over a period of a few hours. These winds can be powerful enough to blow down trees and cause structural damage, putting members of the public at risk.



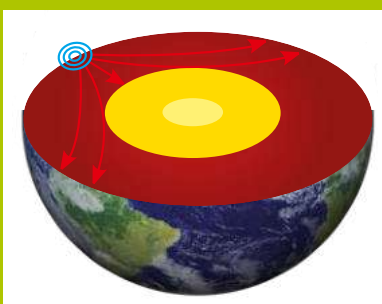
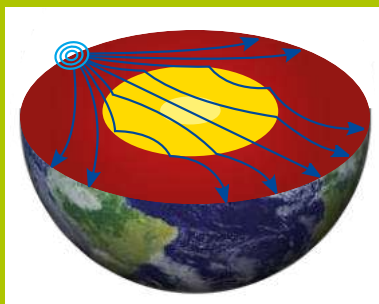
Storm Doris, which struck the UK in February 2017, was classed as a weather bomb

Weather bombs cause converging air to rotate at high speeds, resulting in very severe gusts of wind



Tiny tremors

Storms – including weather bombs – that happen at sea send tiny vibrations known as microseisms through the Earth. This occurs when waves crash together, sending energy into the ocean floor and beyond. The tremors are more subtle versions of those caused by earthquakes, and fall into two categories: pressure waves, or 'P' waves, squeeze and expand the rock, while slower transverse waves, or 'S' waves, wobble the rock from side to side. The P waves are routinely picked up by scientists on the opposite side of the world to their source, but S waves are more illusive. However, in 2014, seismologists in Japan were able to track the source of these slow-moving S waves for the first time, tracing them back to a weather bomb off the coast of Greenland. Researchers hope this breakthrough will open up a new way to study Earth's interior.



Studying tremors that travel through the planet can help scientists better understand Earth's structure

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THE GENIUS OF

DA VINCI

So much more than just a painter, the famous Renaissance polymath invented a plethora of marvellous machines

Leonardo di ser Piero da Vinci was the epitome of a Renaissance man. While renowned as an artist, da Vinci was also a brilliant scientist and engineer. Beyond his famous paintings, such as *The Last Supper* and the *Mona Lisa*, da Vinci's journals reveal a range of studies and observations, from anatomy to astronomy, and palaeontology to philosophy.

The Renaissance ('rebirth') was a period of cultural revival, which began on the Italian Peninsula in the 14th century as the Middle Ages came to an end. Da Vinci was born in 1452 into a world that had become more accommodating to new ideas. A year after his birth, the capital of the Byzantine Empire, Constantinople (now Istanbul), fell to the Ottomans. As talented scientists and artists escaped the war-torn Bosphorus to seek safety in Italian city-states, the country became a hub of learning. One city the fleeing scholars settled in was Florence.

Here they were encouraged to study and invent by the ruling Medici family, who happily bankrolled learning centres all over the city. An intellectual and cultural revolution began; new technological and scientific ideas were spread with help from the recent invention of the printing press, as Europe began to catch up with academics from the Islamic world. It is likely that the inventions and creations of other Renaissance men like Mariano di Jacopo (also known as Taccola) and Filippo Brunelleschi influenced da Vinci, who revelled in the idea of Renaissance Humanism, a notion that encouraged learning and built on critical thinking methods that had stagnated in the Medieval period.

Da Vinci's most famous works are his paintings, but he was also a creative and talented engineer and inventor. The rediscovery of his codices in the 19th century revealed plans

for an array of contraptions, from battlefield tanks to flying machines. His ideas were influenced by classical antiquity and observations of the natural world. For example, a tortoise shell was the inspiration for his armoured car, while observations of birds, bats, flying fish and even plants contributed to the designs of his various flying machines.

His ideas were ambitious, but they were grounded in logical calculations based on scientific theories and mathematical principles. For the most part, these designs were only held back by the technological restrictions of the time. While many of da Vinci's manuscripts were inadvertently destroyed after his death, over 5,000 pages of his journals still exist today, providing us with a glimpse into the mind of a man ahead of his time. Leonardo da Vinci may have died 498 years ago, but the legacy of his creativity and innovation lives on.

FLYING MACHINES

Da Vinci dreamed of mechanisms that would enable humans to soar through the sky

Aerial screw

An ambitious flying machine that helped inspire the modern helicopter

Scribbling in his notebook circa 1489, da Vinci envisioned a spiral-shaped contraption that could take to the skies. Possibly powered by hand cranks turned by four people, his writings suggested that the aerial screw could achieve flight by rotating quickly around a central shaft. Da Vinci believed that air could be compressed, so just as a screw bores into the ground below, his machine could 'bore' into the air above to lift his machine up off the ground.

Unfortunately, materials that were strong and light enough for the device to work were not available at the time. What's more, it would not have been able to fly for long, as once it was off the ground, the screw would no longer have a support structure to press against in order to keep spinning. It may never have made it off the ground, but da Vinci's innovative aerial screw design was the first to study the potential of a rotating spiral for flight.

"Da Vinci's most famous works are his paintings, but he was also a creative and talented engineer and inventor"

A weighty idea

Da Vinci's notes also specify the use of iron wires about five centimetres in diameter. It's predicted that this would have made the device weigh up to a ton.

Materials

Da Vinci's notes mention that the helix section could be made of linen treated with starch. This would help reduce the cloth's porosity and make it more aerodynamic.

Platform

Four men moved around the board, pushing their feet against the platform to turn the hand cranks, causing the rest of the mechanism to rotate.

Lift off?

One hurdle encountered in this study was to figure out how to produce high enough speeds to generate the required lift.

WOULD IT WORK?

Despite resembling a prototype helicopter, da Vinci's invention would not have made it into the air, partly because the power to weight ratio was so low.

Frame

Da Vinci intended for his machine to be constructed from a light and durable material, such as pine.

Lever

The wing was curved and the pilot would use pulleys to flap rapidly and repeatedly.

Ornithopter

Enthused by birds soaring in the air, da Vinci drew some inventive designs for mechanical wings

Da Vinci observed birds and other animals in flight, and became obsessed with the idea of a contraption that would allow humans to do the same. One of his ideas was an ornithopter, which was powered by flapping mechanical wings. Da Vinci wrote over 35,000 words and drew 500 sketches on flying machines. He understood that birds relied on both lift and propulsion to maintain flight, and that they balanced themselves with both wings and tail. He hinted at the idea of gravity and understood that flying machines had to be as lightweight as possible. His sketches demonstrate knowledge of aerodynamics, showing how airflow could be streamlined and how aircraft produce drag. The only drawback was the human body, which is simply not built to achieve flight on its own, nor muscular enough to power a mechanical engine for flight.

WOULD IT WORK?

Ornithopters with flapping wings have been built, both manned and unmanned. They can work with the help of an engine.



WAR MACHINES

Da Vinci devised a number of military mechanisms that could have revolutionised the battlefield

Armoured car

Da Vinci's concept could be considered a distant ancestor of the World War One tanks

Incorporating past designs for armoured weapons, da Vinci's tortoise-like cannon system had the ability to move over flat terrain and would have been powered by an eight-man team. Oxen and horses were initially intended to provide the power, but space inside the car was limited. The operators were protected by a slanted and sturdy covering, and a turret on top was used as a viewpoint to help the drivers navigate. The armoured car was a good idea on paper, but a number of issues meant it could never have worked. Like the aerial screw, the human body simply didn't have the muscle power to move it, and the thin wheels meant the tank would easily sink in mud.

"His ideas were ambitious, but they were grounded in logical calculations"

Armour

The plated sloping design proposed by da Vinci was possibly superior to WWI tank armour, as the 45-degree angle would help deflect the impact of enemy projectiles.

Power train

Da Vinci recommended that his armoured car be powered by a team of eight men, operating hand cranks that turned the wheels.

Turret

The men inside would have likely accessed the turret with a ladder and used it to view the battlefield and signal tactics to allies.

Cannons

Regularly placed around the car's circumference, the guns could fire in any direction on the battlefield.

WOULD IT WORK?

If da Vinci's illustration was followed, the shafts would turn the wheels in opposing directions, preventing the car from moving. It's thought this was a deliberate error in case his designs fell into enemy hands.

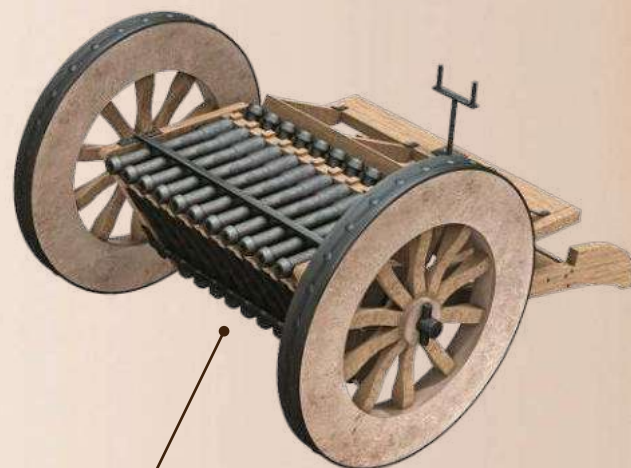
The bombard

Another weapon that da Vinci depicts in his notebook is a bombard that launched fragmenting ammunition.



Rain of metal

Once it was fired, the cannonballs would separate into several pieces, raining down lethal shards of metal on enemy infantry.



Wheels

Despite including studs on the wheels to add friction, it is likely the armoured car would have got stuck in boggy and uneven ground.

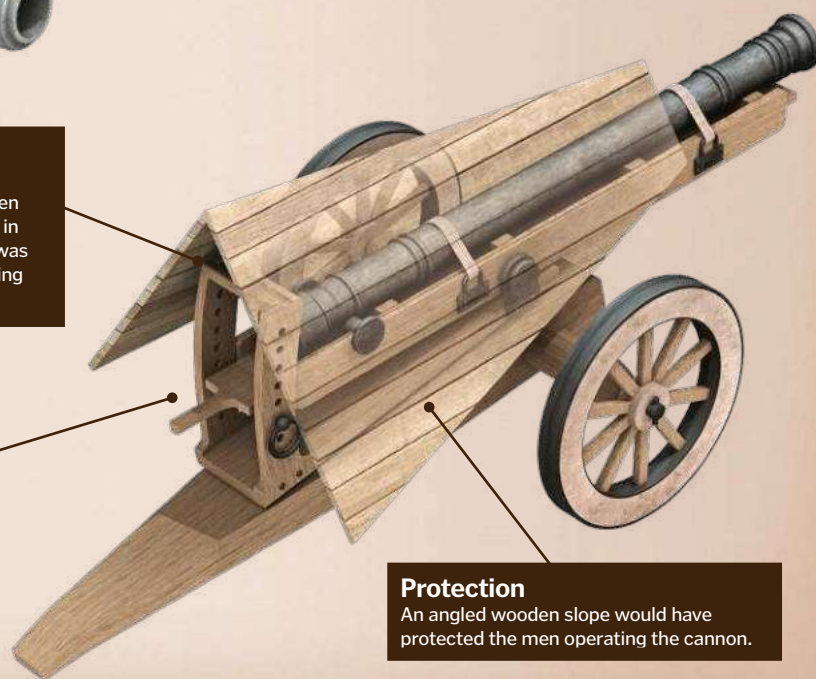
Machine gun

A multi-barrelled weapon that could unleash rapid-fire projectiles at hordes of enemy soldiers

Cannons were important in Renaissance-era artillery. Da Vinci aimed to add maneuverability and extra firepower with his concept of a multi-barrelled war machine that could fire a dozen cannonballs at once. With wheels on its side, the portable muzzle-loaded cannon had a rotating body with up to three revolving rows of guns. One could fire while the other two cooled and were reloaded. The recoil would have been fierce, so the machine was equipped with a support bulkhead that held the main body in place. In one of da Vinci's sketches, the barrels are arranged in a fan shape to give the weapon a wider firing range.

Recoil

The cannon was encased in a wooden structure to hold it in place. Although it was heavy, accurate firing was not difficult.



Protection

An angled wooden slope would have protected the men operating the cannon.

Springald

A cannon intended to eliminate specific targets from the battlefield

The springald was an artillery device that existed before da Vinci, but like many of his other creations, he built upon the idea. His version had the ability to fire in many directions both horizontally and vertically. An elevating arc moved the springald up and down, and when the desired height was achieved, it was held in place by a cylindrical peg. It could then be aimed to the left and the right. Iron and stone cannonballs, and even metal-tipped arrows were fired from the breech-loaded cannon.



HYDRAULIC MACHINES

Da Vinci's notebooks feature several ideas for complex yet workable devices powered by water

Paddleboat

This reciprocating-motion vessel was a huge advance on the oar-powered boats of the age

With the absence of internal combustion engines, boats and ships in the 15th century were powered either by wind or by oar. Writing between 1487 and 1489, da Vinci reasoned that a paddle-based mechanism that used reciprocating motion (repetitive back and forth movements) would be far more effective. By replacing the oars with paddle wheels, it would be easier for the boat to travel upstream.

The paddleboat wasn't an original da Vinci idea; Italian inventors Taccola and Francesco di Giorgio had both looked into the concept before, but this was the most realistic and workable proposal

yet. The operators would push down on alternate foot pedals, which powered a reciprocating-motion system, which in turn was transformed into rotary motion to turn the paddle wheels and propel the boat forwards. The principle was the opposite of a water mill, with the machine moving the water rather than the water moving the machine.



1 Pedal

The mechanism starts with the operator pushing down on one of the two pedals.

2 Motor

The reciprocating motion produced by the pedal is transformed into rotary motion by a series of cranks, springs and gears.

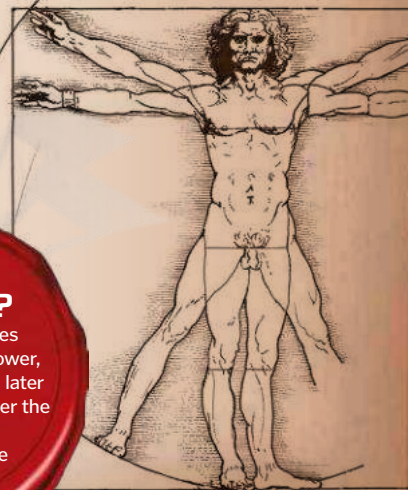
3 Paddles

The rotary motion produced by the motor turns the paddle wheels to propel the boat forwards.

"The inventions of other Renaissance men most likely influenced da Vinci's own ideas"

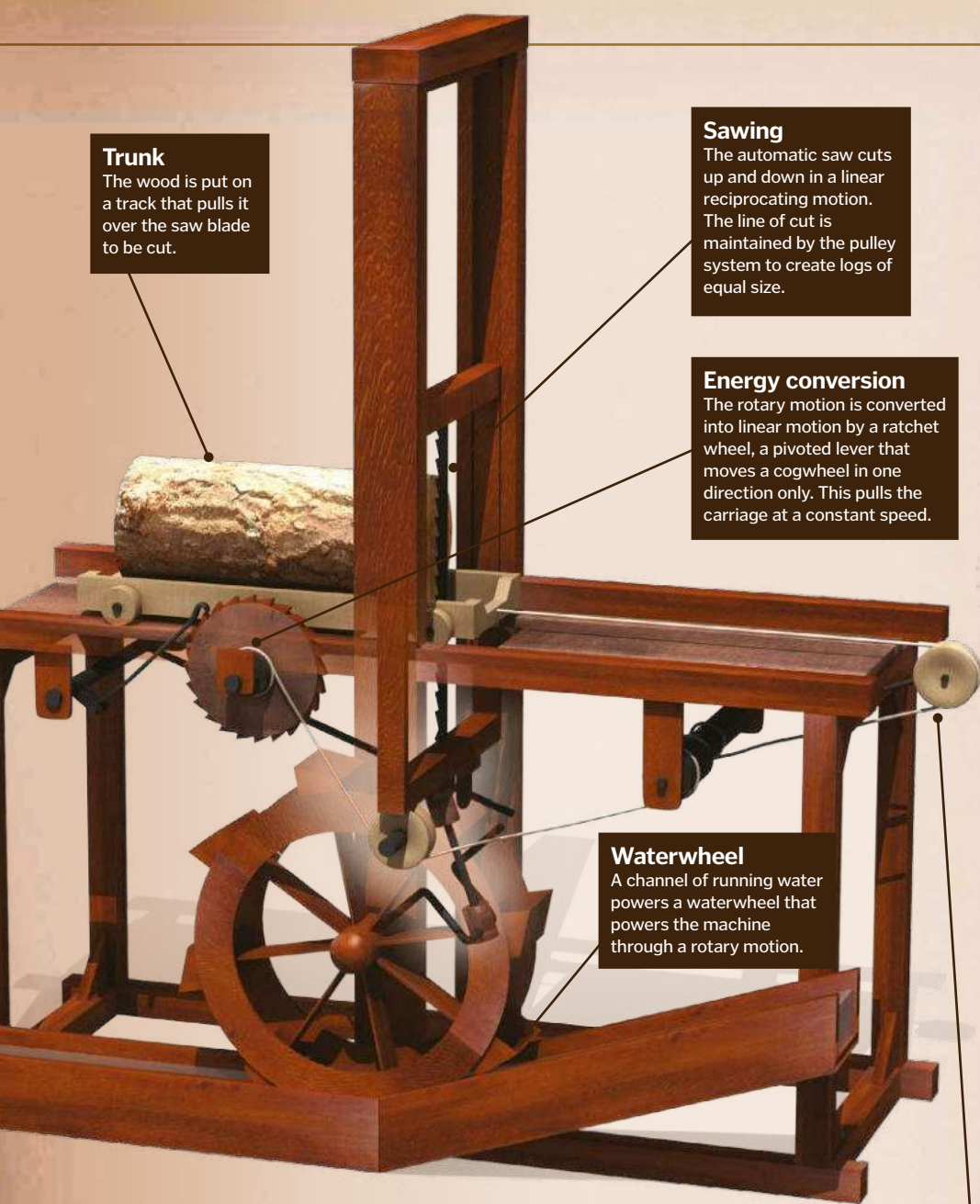
4 Reciprocation

The operators alternately press on the left and right pedals to keep the paddle wheels spinning.



WOULD IT WORK?

Using steam engines rather than human power, the paddle wheel was later used extensively all over the world, notably in Mississippi paddle steamers.



Trunk

The wood is put on a track that pulls it over the saw blade to be cut.

Sawing

The automatic saw cuts up and down in a linear reciprocating motion. The line of cut is maintained by the pulley system to create logs of equal size.

Energy conversion

The rotary motion is converted into linear motion by a ratchet wheel, a pivoted lever that moves a cogwheel in one direction only. This pulls the carriage at a constant speed.

Waterwheel

A channel of running water powers a waterwheel that powers the machine through a rotary motion.

Pulleys

The mechanism is run using pulleys that gradually move the carriage as the wood is sliced.

Mechanical saw

Another hydraulic invention that was designed to cut wood quickly and efficiently

Noted down circa 1478, da Vinci's mechanical saw was a rapid cutting device. The saw utilised the energy of a water mill to power the slicing of logs into wood. The wood would then be used for construction, particularly in war time, where it would be used to quickly build military bridges (these bridges were easy to transport and could be rapidly assembled across a body of water to allow troops to cross).

The saw's mechanism was relatively simple: a channel of running water turned a mill, and this rotary motion was transformed into linear reciprocating motion that powered the up and down sawing movement. The mechanism also powered pulleys and crankshafts that kept the log moving towards the saw. Like the paddleboat, the mechanical saw had been thought of before but not in this level of detail. Once again, da Vinci took a clever concept and improved it.

WOULD IT WORK?

The mechanical saw was one of da Vinci's least innovative but most workable concepts. Its automatic cutting system worked using the same principles as a standard water mill.

DA VINCI INVENTIONS USED TODAY



Ball bearings

First seen in a drawing in 1497, da Vinci based his idea on ancient Egyptians rollers that were used to transport huge stones up ramps to construct the pyramids.



Double hull

Da Vinci proposed the idea that a double hull would stop ships from sinking if its first was pierced by an enemy ship's ram, a weapon commonly used in naval battles.



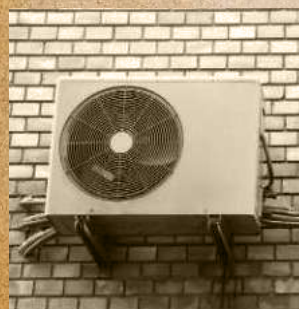
Parachute

Da Vinci devised this combination of linen cloth and wooden poles 300 years before the first parachute test. His design was tested in 2005 and was proved to work.



Robot

Using a system of pulleys, weights and gears, da Vinci's robot was a moving suit of armour that could move its limbs, turn its head and sit down and stand up.



Air conditioning

After being asked to help ventilate a boudoir, da Vinci developed a mechanical water-driven fan in 1500 that can be seen as a precursor to modern cooling systems.



3,000

The number of words Shakespeare is believed to have introduced to the English language

Shakespeare's plays have been translated into over

80
LANGUAGES

Shakespearian phrases used today:

- **Wild goose chase**
- **Heart of gold**
- **Vanish into thin air**
- **Faint-hearted**
- **All of a sudden**

5

Candidate ghostwriters

There's a debate as to whether Shakespeare actually wrote all of the plays that are attributed to him. Potential ghostwriters include:

BEN JONSON
SIR FRANCIS BACON
EDWARD DE VERE
CHRISTOPHER MARLOWE
WILLIAM STANLEY

80

Recorded variations of spelling 'Shakespeare', including:

SHAPPERE
SHAXBERD
SHAKESPE
SHAXPER

MODERN INFLUENCE

Films and musicals based on Shakespeare's plays include:

THE LION KING (*HAMLET*) **WEST SIDE STORY**
(*ROMEO & JULIET*) **10 THINGS I HATE ABOUT YOU**
(*THE TAMING OF THE SHREW*)



ROYAL FANS

The bard was also an actor and performed in front of Elizabeth I and James I in private shows.

SHAKESPEARE WROTE

37
PLAYS &
154
SONNETS

52

The age Shakespeare died. His cause of death is unknown, but evidence suggests he caught a fever.

WILLIAM SHAKESPEARE

The life and works of the world-famous Elizabethan bard and his timeless plays

William Shakespeare was one of the most prolific and renowned writers of all time. He was born in Stratford-upon-Avon in 1564 and later moved to London to pursue a career in theatre. His plays were split into tragedy, comedy and history and were often based around a main character with a fatal flaw.

Shakespeare was part of the Lord Chamberlain's Men (later the

King's Men) Theatre Company that performed at London's Globe Theatre. He popularised the use of non-rhyming iambic pentameter; a verse with five sets of unstressed syllables within ten-syllable lines.

His most famous plays include *Romeo & Juliet*, *Hamlet* and *A Midsummer Night's Dream*. Even 400 years after his death, many of his works are still performed and studied all over the world.



"I never see thy face"

There are no portraits of Shakespeare confirmed to have been painted by observing the playwright. The Chandos portrait (above right) is probably the most accurate, but we can't be certain what the bard looked like.



Mining in Roman Britain

The invasion of Britain provided the Roman Empire with new sources of valuable ore

Claudius' invasion of Britain began in 43 CE, and as his army conquered more land, the Romans gained access to the region's rich mineral seams. Mining was an important industry for the Romans, who used the ores to make tools, jewellery and weapons. During their rule, iron, copper, tin, lead, silver and gold mines were constructed across Britain.

The Romans used several different mining techniques, and pioneered hydraulic methods. Hushing was used to extract ore near the

surface, and involved redirecting a river to unleash a torrent of water that removed topsoil to reveal the metals. In other areas, strip-mining was used to extract shallow minerals by removing the overlying ground.

Subterranean mining was a much larger operation and was only used to unearth the most valuable ores: silver and gold. Narrow vertical shafts were used to penetrate into the rock until ore was found, and these would then widen into horizontal tunnels called galleries as

mining took place. Without explosives, fires were likely set in the tunnels to expand and crack the rock. The weakened rock could then be drenched in water, which caused it to contract rapidly and disintegrate. The workers, who were usually soldiers, slaves or local people, used stone and iron tools in the form of hammers, picks, bars and wedges to extract the metals. Britain became a huge mining centre within the empire, and the scale and sophistication of the work was not equalled until the Middle Ages.

● Iron

33 iron mines existed in Roman Britain, with the majority in The Weald area of Southeast England.

● Tin

With its operations centred in Cornwall and Devon, tin was mined to make coins and be mixed with other metals to make alloys.

● Gold

Roman Britain only had one area dedicated to mining gold, which was in Wales at Dolaucothi. The gold was locked inside seams in quartzite rocks.

● Copper

The Romans already had copper mining operations in Spain and Cyprus, but it was still excavated to mix with tin to make bronze.

● Silver

Silver was only found alongside lead in Britain, and the two minerals were separated by being heated in a process called cupellation.

● Lead

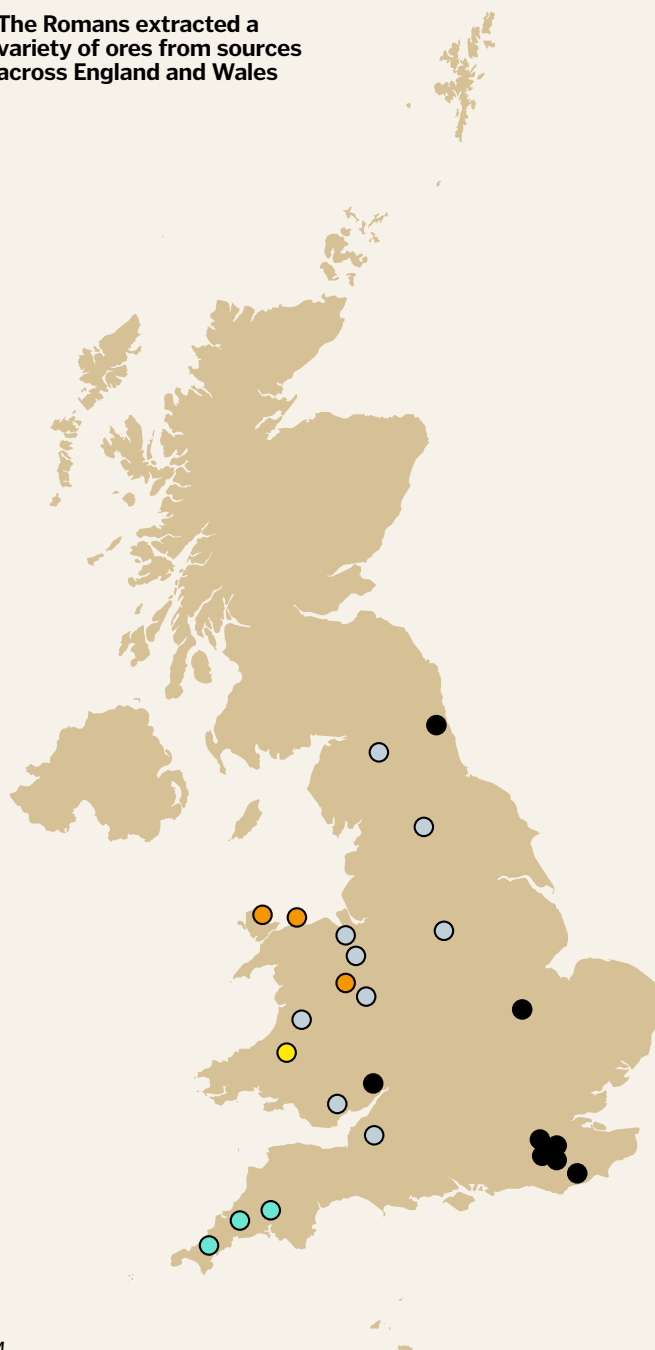
Perhaps the most important Roman commodity, Britain overtook its closest rival Spain as the main lead producer in 70 CE, causing miners in Spain to complain.

Other minerals

Coal, marble and stone were also mined. Coal was used to heat baths and hypocausts; very important for the Mediterranean invaders not used to wet and windy Britain!

Mine locations

The Romans extracted a variety of ores from sources across England and Wales



12 per cent of miners under Roman rule died each year from falling rocks and lung diseases

British gold mines

The Dolaucothi gold mines were constructed in Roman-controlled Wales in 70 CE. The rich seam was mined both on the surface and underground, with shafts dug almost 50 metres into the ground using just hammers and picks. Water was brought to the site from local rivers via aqueducts to power machinery and help wash away soil to reveal the ore. A fort was built at nearby Pumsaint to protect the mine and its valuable commodity from Celtic revolts.

Roman coins found in the area indicate that mining activity continued until around the 4th century, after which the mine was largely abandoned until it was reopened during the Victorian era. Today, the site is owned by the National Trust, with parts of the mines open to the public.



It is estimated that one ton of gold was extracted from the Dolaucothi mines before they were closed in 1938



Star forts

Huge, multi-angled strongholds were built as an effective defence against cannon fire

Concentric stone castles were becoming obsolete by the 15th century.

Advancements in military engineering had created cannons capable of levelling stone battlements with ease. The solution was the star fort.

First constructed in Italy, angled triangular bastions allowed defenders to provide covering fire from almost any angle with no 'dead space' for attackers to shelter in. The walls were made from brick, which was much more durable against cannon fire, and were sometimes several metres thick. Star forts were replicated across the world, and stood firm until the Napoleonic era, when explosive shells proved to be their undoing.

Charles Fort

How this 17th century Irish star fort helped defend the port of Kinsale

Ammunition dump

The gunpowder store had inner and outer walls to shield other buildings in case of an explosion.

Seaward defence

The Devil's and Charles' bastions were key parts of a structure almost impregnable to naval attacks.

Sentry towers

The North, Cockpit and Flagstaff bastions had sentry points that guarded against the threat of inland assaults.

Facilities

The fort housed a garrison of up to 200 men and featured soldiers' quarters, parade grounds, barracks, stables and even a hospital.

"Triangular bastions allowed for covering fire from almost any angle"

Lombe's silk mill

The world's first mechanised factory that helped kick-start the Industrial Revolution in Britain

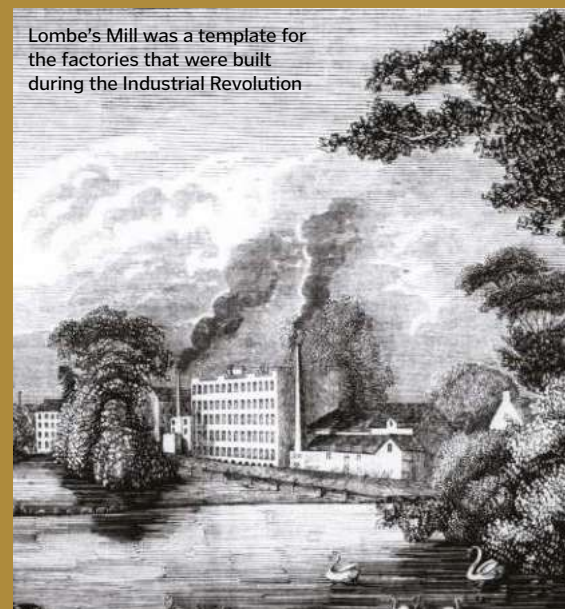
In the early 18th century, Italy led the way in silk production, with English machines piling in comparison to their technology. Thomas and John Lombe were two aspiring silk merchants from Norwich who wanted to learn the Italian trade secrets for themselves.

In 1714, John travelled to Livorno to witness it for himself. Working at one of the silk shops, he was amazed to see the fibre being twisted and doubled by machines to form a multi-threaded yarn. Unbeknownst to the Italians, at night he sneaked into the shop and secretly made note of what he saw. John

returned to Britain and immediately gained a patent for these advanced machines that could wind, spin and twist silk. The brothers' spinning mill in Derby was a huge success and became the first factory with a continuous production stream. The Lombe business, boosted by the new machines, went from strength to strength and the factory employed 300 workers at its peak.

John Lombe died in 1722 from poison, which was reportedly given to him by a female agent sent over from Italy as revenge for stealing their trade secrets.

Lombe's Mill was a template for the factories that were built during the Industrial Revolution



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HOW IT
WORKS

BOATY MCBOATFACE

AFTER CAPTURING OUR
HEARTS, BOATY
MCBOATFACE IS NOW
CAPTURING SOME
SERIOUSLY COOL
SCIENTIFIC DATA

In March 2016, the National Environment Research Council (NERC) ran a competition to name its new polar research vehicle. One suggestion, Boaty McBoatface, caught the public's attention and swept the popular vote. The NERC decided to name the ship itself after one of the runner-ups, RRS Sir David Attenborough, but compromised by using the public's favourite choice for one of the ship's accompanying unmanned submersibles.

Boaty is an Autosub Long Range vehicle, designed to collect important data about oceanic conditions in the polar regions. Onboard batteries provide enough power for Boaty to travel 6,000 kilometres at a steady 0.4 metres per second on a single charge. The sub can roam the oceans for up to six months at a time, periodically sending the data it collects back to scientists via a radio link. With the data Boaty collects, researchers hope to better understand how the ocean is affected by climate change.

WINGS

The wings either side of the torpedo-shaped body help to steer the craft.

TITANIUM BODY

Boaty's body is made of titanium, as it is both light and strong.

CURRENT SENSOR

The Seabird SBE 52 moored profiler is able to measure water conductivity, pressure and temperature and store the data using little power.

"Boaty can roam
the oceans for
up to six months
at a time"

RESEARCH VESSEL

The RRS Sir David Attenborough will have a range of over 35,000 kilometres and be able to break through metre-thick ice.

IRIDIUM SATELLITE LINK

Boaty transmits its data via an Iridium satellite data link – a network of satellites covering the entire globe.

FIBRE OPTIC SENSOR

As GPS doesn't work underwater, Boaty's course is set on the surface. It then uses a fibre optic gyroscopic sensor to navigate when submerged.

RRS SIR DAVID ATTENBOROUGH

When it launches in 2019, Boaty's parent ship, the RRS Sir David Attenborough, will be one of the world's most advanced polar research vessels. The 128-metre-long ship will be packed with state-of-the-art technology and have room for up to 60 scientists. A key feature will be a moon pool; a four by four-metre shaft running through the ship, through which scientific instruments can be deployed and retrieved.

THRUST

The thrusters and propeller at the rear of the craft give Boaty small boosts of speed.

MEASURING FLOW

Boaty uses an Acoustic Doppler Current Profiler to measure the speed of the current flow in the Antarctic Ocean.

BOATY'S FIRST MISSION

While the RRS Sir David Attenborough is still under construction, in March 2017 Boaty set out on its maiden voyage aboard the RRS James Clark Ross. The sub's first mission is to investigate changes to the Antarctic Bottom Water (AABW). Wind changes in the Weddell Sea are thought to be causing the AABW to move more rapidly. This makes it more turbulent and causes more mixing with the warmer overlaying waters, resulting in warming and contracting of water in the AABW. Boaty is currently patrolling the bottom of the Orkney Passage, just off the Antarctic Peninsula, helping to measure ocean turbulence in the area. The information it sends back will aid scientists in building models that show how and why the AABW, one of the deepest abyssal masses, reacts to these changing Southern Ocean winds.



SAN FRANCISCO'S CABLE CARS

Uncover the mysterious methods used to power the city's iconic transport network

As they travel up and down the steep city streets, San Francisco's iconic cable cars appear to be effortlessly gliding along with no means of propulsion. Unlike traditional cable cars that hang in the air, these tram-like carriages crawl along the road, yet have no visible overhead wires providing power. Instead, they are driven by cables underground, continuously running in loops beneath the tracks. All the cars have to do is grab hold of these cables using a grip device below the carriage that reaches through a slot in the road. Once attached, they get pulled along for the ride, and simply have to let go when they want to stop.

This simple yet effective mechanism has been driving the cars since they were first introduced in 1873 as part of the world's first practical cable car system. By 1890, 23 lines had been established, but as buses and electric trams became more efficient, the service was scaled back. Today, it is the world's last manually operated cable car system, and is comprised of just three lines driven by four cables; one for the California Line, one for the central Powell Line and one each for its outer ends: Powell-Mason and Powell-Hyde.

The thick steel cables are driven by electric motors located in a central powerhouse and

travel at a constant speed of 15 kilometres per hour. As they leave the building they are slathered with pine tar, which not only helps to protect them but also helps the cars start more smoothly. When the grip first takes hold, the tar acts as a lubricant, allowing the cable to slip a little through its grasp while the car gets up to speed. The pressure of the grip causes the tar to heat up and vaporise, eventually resulting in full metal-on-metal contact and a tighter grasp.

Despite the added layer of protection, the cables typically only last between six to eight months on average. At the powerhouse, they pass through a strand alarm that signals to the

Cable car mechanics

The inner workings of a cable car that make it stop and start

Grip lever

This lever can be pulled to close the grip around the cable or pushed to release it.

Emergency brake

Pulling this lever forces a 45cm steel wedge into the slot between the tracks, stopping the cable car immediately.

Track brake

This lever presses a 60cm block of wood – located between each wheel set – down onto the track to slow the car.

Cable

Over 3cm in diameter, the cable consists of six steel strands made of 19 individual wires, all wrapped around a sisal rope core. It's driven by a 380kW electric motor.

Wheel brake

Pressing down on this foot pedal pulls steel brake shoes against each wheel to stop them turning.

Bell

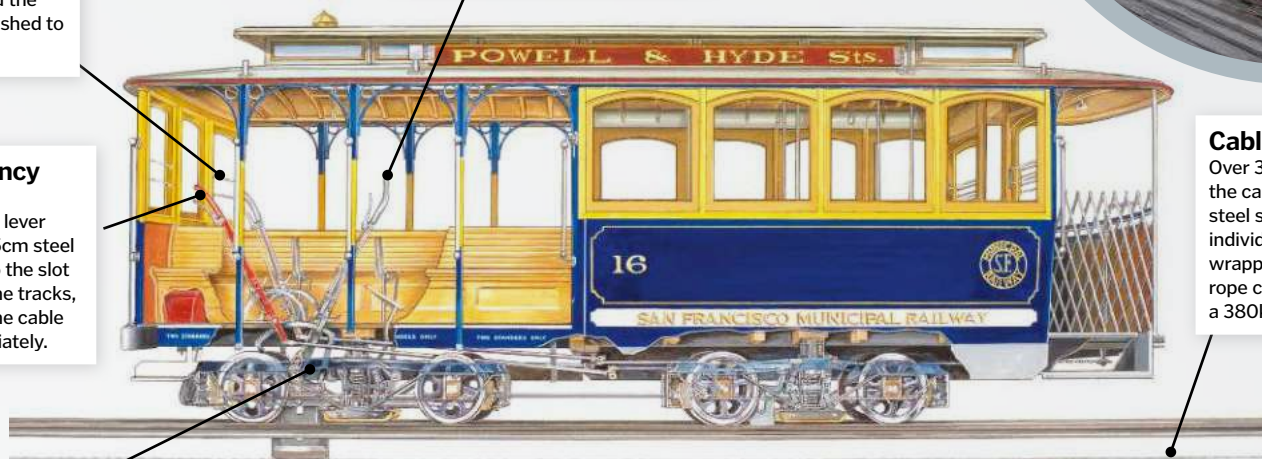
When approaching an intersection, the bell can be rung to warn motorists and pedestrians that a cable car is crossing.

Track

Between the steel rails that the wheels run along is a channel containing the cable and a slot through which the grip grabs it.

Grip

The mechanical grip acts like a pair of pliers, latching onto the cable that pulls the car along.



Turning around

When the single-ended Powell Street cable cars reach the end of the line, they are turned around on giant turntables. These rotating platforms sit on top of steel rollers that allow them to move while the cable is passed round a spinning sheave located behind them.

As the car approaches the turntable, the gripman drops the cable and coasts onto it before applying the brakes. They then get out and, with the help of the conductor, pull or push the car around by hand until it is facing the right way. In the past, the waiting passengers would sometimes help with this task, as it meant that they could jump on as soon as the car had been turned around and get the best seats. However, nowadays, they must wait in a queue until the car is safely off the turntable.



The turntables are manually powered by the gripman and conductor



Taking hold

How cable cars adjust their grips to traverse San Francisco's streets

Latch release

Pulling this latch will hold the grip lever in its current position, even if the gripman lets go.

Gripping

As the grip lever is pulled back, the grip tightens around the cable and the car accelerates. Starting is smooth because the cable is lubricated with pine tar, which allows for a slower grip as the liquid heats up and vaporises.

Gripped

The further back the grip lever is pulled, the stronger the grip on the cable. Gripping the cable loosely will pull the car more slowly, while a tight grip will pull it along at the cable's maximum speed of 15km/h.

Grip

The grip weighs 148kg and features two jaws that squeeze tightly around the cable.

Adjustment rod

To travel up steep hills, the grip can be adjusted to squeeze even more tightly on to the cable and prevent slipping.

Partial release

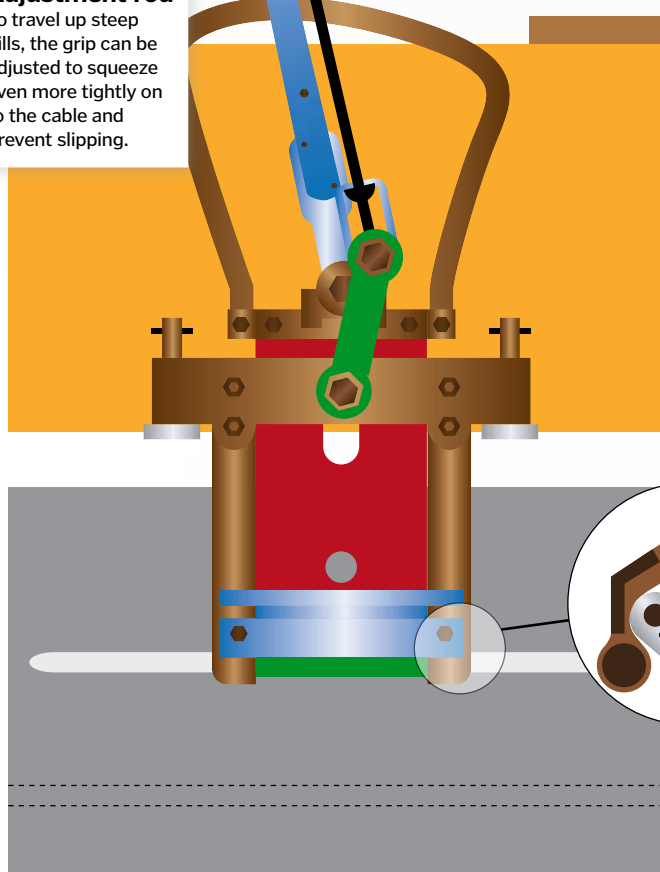
When stopping to let passengers on and off, the grip lever is pushed halfway forward. This opens the grip enough to let the cable slide through, but does not drop it completely so it does not need to be picked up again.

Full release

At cable crossings, Let-Go curves and the end of the line, the grip lever is pushed all the way forwards to release the grip completely and drop the cable.

Dropped cable

A cable lift lever or a dip in the track is needed to allow the grip to pick up a dropped cable.



The history of these icons of transport

How a London-born gold miner's idea revolutionised the Golden City

1869

Andrew Hallidie first has the idea for a cable driven rail system after witnessing a horse-drawn streetcar accident.



1873

Hallidie's cable-operated Clay Street Hill Railroad begins public service and is later copied by other operators.

1889

By now, a series of cable car companies are operating 23 lines covering 85 kilometres of track.



1892

Electric streetcars are introduced to the city, proving cheaper, quicker and more flexible than the cable cars.



"San Francisco hosts the world's last manually operated cable car system"

crew when a strand has come loose. The entire line is then shut down that evening and a new cable is spliced into the feed.

As the cables travel beneath San Francisco's streets, they are held in place by a series of pulleys located along each route. Without them, the cables would rise out of the slots at the bottom of each of the city's many hills, making it impossible for the cars to grab on. The pulleys keep the cables running along the bottom of their channels, lower than the reach of the cable car's grip. In order for the car to grip it, it must either pass over a dip in the tracks, lowering the grip down to the cable, or a cable lift lever in the street is pulled to elevate the cable.

The job of operating the cable car's grip belongs to the gripman, who uses the grip lever to 'take' or 'drop' the 'rope', the colloquial term for the cable. It's a task that requires strength as well as skill, as there are no markings indicating the amount of grip being applied to the rope. The gripman must be able to feel the grip's position so that they know when a tighter or looser grip is needed. Focus is also required, as they need to adjust the grip lever several times on each trip.

For example, when steel plates or bright yellow lettering painted on the street warn the gripman to 'Let Go', they must 'drop rope'. This could be for one of several reasons, including that there is a pulley beneath the track that the grip could collide with or that the car is approaching a 'Let-Go' curve, where the cable is diverted around a wheel, or sheave. At these points, the cable is released and the car continues on its path using only inertia, before 'taking rope' again on the other side.

A similar process is required at the point where the Powell and California Lines cross. Because the California Line was built first, its cable runs above that of the Powell Line, and so its gripman can simply continue over the crossing as normal. However, if the Powell Line gripman did this, their car's grip would collide with the California Line cable, causing a lot of damage. Therefore, when a Powell Line car approaches this crossing, the gripman must drop rope, coast across, then take rope on the other side. Today, this is the only intersection on the cable car system, but in the past there were many more. When the last line first opened in 1891, its gripman had to drop rope 22 times.

On the very rare occasion that the gripman fails to let go when prompted, there is a safety mechanism in place. As the car approaches, the cable will raise a bumper bar, which drops counterweights and turns the pulley against the cable. This causes an alarm bell to ring, alerting



Grip operators require strength, coordination and balance

the gripman to drop rope. If they still don't release the cable, the bumper bar will then force it out of the grip, causing only minor damage that can be quickly repaired.

The only other occasions when a gripman has to drop rope is when a Powell Line car has to release one cable and pick up another, or at the end of a line. On the California Line, setting up the cars for their return trip is relatively easy because they are double-ended. A system of switchbacks and crossovers are used to get the car on the right tracks, and then the gripman simply has to change position as there is identical machinery at each end of the carriage. On the Powell Line, however, the cars are single-ended and so a turntable is used to rotate the entire carriage before it is able to continue on its journey.

The powerhouse

Originally one of many, San Francisco's solitary powerhouse runs its entire cable car network

If the moving cables drive the cars, then what drives the cables? The answer can be found in a building called the powerhouse, located on the corner of Washington and Mason Street. In the past, each cable line had its own powerhouse, which used steam engines as a power source. Today, electricity is used to drive all the cables from one central hub.

Inside the powerhouse, a set of four 510-horsepower electric motors each

drives a pair of wheels, known as sheaves, measuring four metres in diameter. Each pair of sheaves has one of the four cables wrapped around it in a figure of eight pattern, pulling it at a constant speed of 15 kilometres per hour through the channels in the city's streets. As the cables tend to stretch over time, the rear sheave in each pair is built to be adjustable, enabling it to be moved back to maintain a constant tension.



Large wheels drive the cables from inside the powerhouse

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1906

A powerful earthquake destroys powerhouses, cable cars and lines, many of which are replaced with electric streetcars.



1947

Mayor Roger Lapham proposes the closure of the cable car system, but the citizens vote to keep it running.



1982

The cable car service is suspended for almost two years while powerhouses, tracks and cars are refurbished.

1984

The upgraded cable car service begins operation and four days of festivities are held to celebrate the occasion.

Formula E race engineer

Behind the scenes on race day at the electric-powered street racing series

Josep Roca is one of the race engineers for Panasonic Jaguar Racing, one of ten teams in the FIA Formula E championship, now in its third season. Josep has worked in motorsport for ten years and has engineered and toured grand prix cars in different championships around Europe. He was part of team that created the Jaguar I-TYPE, the car the team uses in Formula E. As race engineer, Josep's responsibility is to provide the fastest car possible for every race and act as the link between the driver and the technical team.

Josep gives Panasonic Jaguar Racing driver Mitch Evans a final brief before he heads out to the track

During a race, Josep (left) is the relay between the driver and the technical team



In Formula E, alterations to the car's hardware are limited so teams have to make the most of their software to extract the car's full potential



WAKEUP CALL 5.20am

Wearing my team kit, I double-check my laptop is in my rucksack and that I have my entry pass. I meet the rest of the team at reception and we walk together to the city centre racetrack, which is near our hotel. The adrenaline soon starts pumping and I mentally start to review everything we have planned for the busy day ahead.



OPENING THE GARAGES 6.30am

We have one and a half hours before the cars are out on the track. All the work has been completed the night before so we just have to do system checks, confirming tyre pressures and switches and settings while also briefing the crew and my driver Mitch Evans. Headsets on, we prepare for the first practice session, which will prepare us for qualifying and the actual race.



PRACTICE SESSIONS 8am

Mitch is strapped in five minutes before the lights go green. Radio checks are made as he warms up the tyres and the



"The race revolves around strategy, energy levels, pit stops and track position"

Josep's job is to help Mitch achieve the fastest lap time with the lowest energy usage



brakes on the first lap. We then undertake our run plan, which includes 170kW push laps, energy saving laps, 200kW laps, switch settings and car change practice. We must gather all the data we can to validate our race strategy.



DEBRIEF 11.05am

With the data from the practice now downloaded onto our servers, Mitch talks us through what he felt in the car, corner by corner for all the different setups. The I-TYPE needs to be ready in less than 50 minutes for qualifying, including charging its battery, set up changes and service. Quick decision-making and team coordination is crucial.



ON THE STARTING GRID 3.20pm

After the qualifying session, we have two hours to get everything ready for the race. We prep both cars, re-run energy simulations and confirm the feasibility of our strategy. On the grid, I confirm the strategy and the switch sequences with Mitch. With five minutes go, I wish Mitch good luck and do our last radio checks. We're ready to race.



THE RACE 4.04pm

For the next 50 minutes, everything revolves around strategy, energy levels, pit stop lap options and track position versus competitors. At the end of every lap, Mitch relays back his energy usage over the radio. I cross check this figure with our energy strategy, recalculate if required and relay back what we need him to do for the next lap. This is the most intense part of the day.



ONTO THE NEXT EVENT 5pm

After the chequered flag is waved, we have the race debrief with the full engineering and management team. This is when we discuss how the race went. Cars, tools, spare parts, garage structures and equipment are put in their transport boxes ready for the next event. My day comes to an end as it started, with a quiet walk back to the hotel while mentally recapping the incredibly intense and exciting day that we have just been through.



How superchargers and turbochargers work

Which forced induction system is the best? We examine the key differences...

It is likely that if you're a bit of a petrolhead, you will have heard the words 'supercharger' and 'turbocharger' at some point. But what exactly are they?

Beginning with the former, superchargers – commonly referred to as a forced induction system – are devices fitted to a vehicle's internal combustion engine that help it produce more power. To produce more power, you need to combust more fuel, and to do this you need more air. A supercharger compresses the intake air,

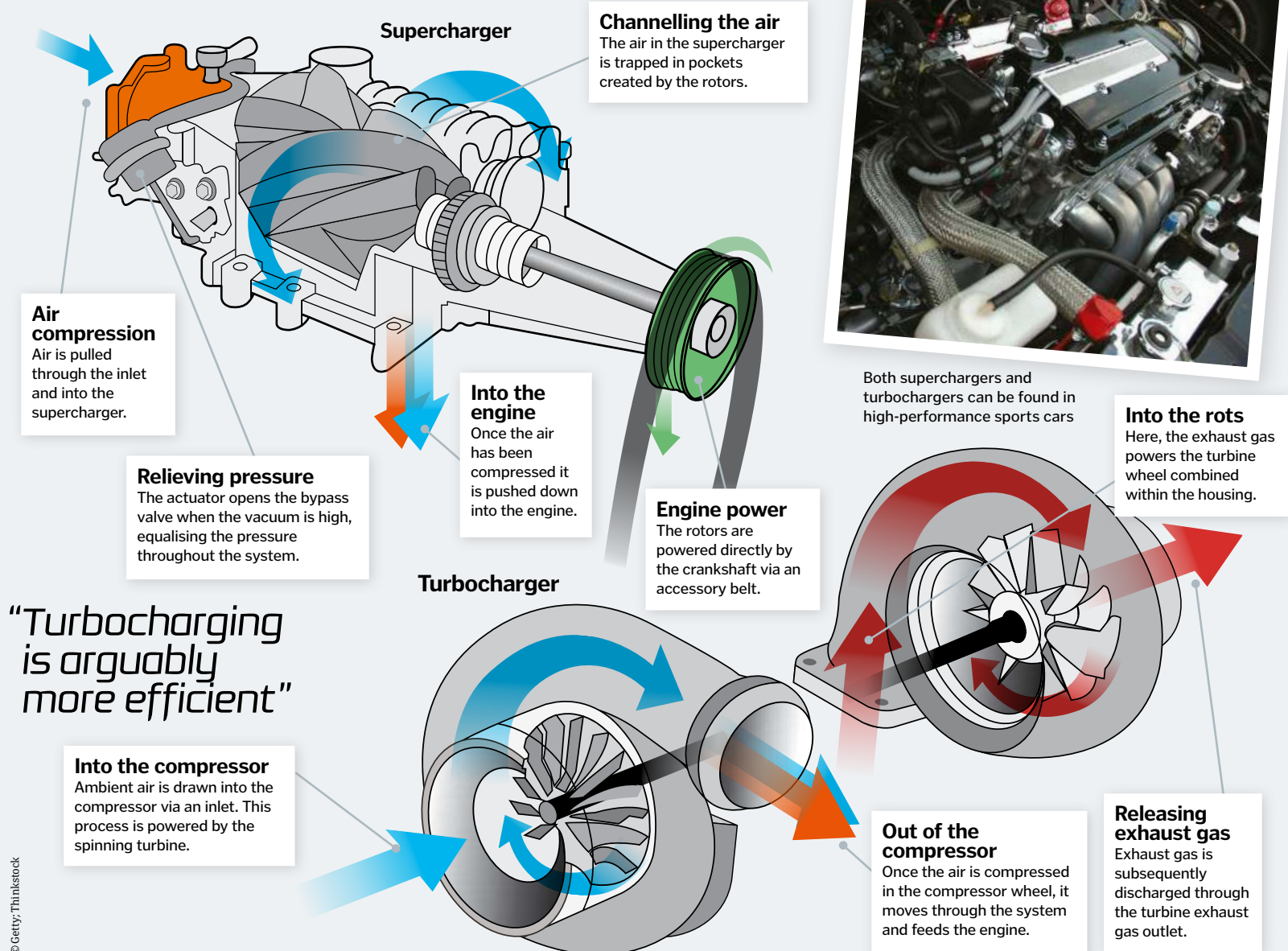
forcing more air into the engine per cycle. This allows more fuel to be combusted, boosting the engine's power.

Turbochargers follow the same principle and aims as superchargers, although there are some key differences between the two. The main one is with regards to its power supply. While the power superchargers get is received directly from the engine, turbochargers are powered by the exhaust stream running through a turbine, which subsequently spins the compressor.

As a result, turbocharging is arguably the more efficient of the two processes since it does not require power from the engine and the energy being used in the exhaust stream was otherwise going to be wasted. Plus, superchargers tend to be a lot more expensive than turbochargers, despite being easier to install. Even so, due to the pressure turbochargers exert on the exhaust system, they don't tend to be as effective unless the engine is running at higher revs per minute (rpm).

Superchargers vs turbochargers

Stacking up the inner workings of these engine-boosting systems



Zeppelins

Inside the behemoths of the sky that were used as both luxury liners and deadly bombers

First developed in Germany in the late 19th century by Count Ferdinand von Zeppelin, zeppelins were rigid airships packed full of lighter-than-air hydrogen. The lightest element on the periodic table was ideal for lift but was also highly flammable. Although safety

precautions were undertaken, accidents did happen, most notably in the Hindenburg disaster of 1937, which claimed 36 lives.

When they were introduced, these huge airships made long-distance commercial air travel achievable for the first time, with

passengers enjoying leisurely voyages in luxurious cabins. However, at the outbreak of World War One, zeppelins were used by the German military as bombers and anti-aircraft vessels, carrying out many bombing raids across Europe.

Zeppelins were equipped with machine guns in WWI



Frame

Metal girders and rings made up a zeppelin's rigid skeleton.

Gas bags

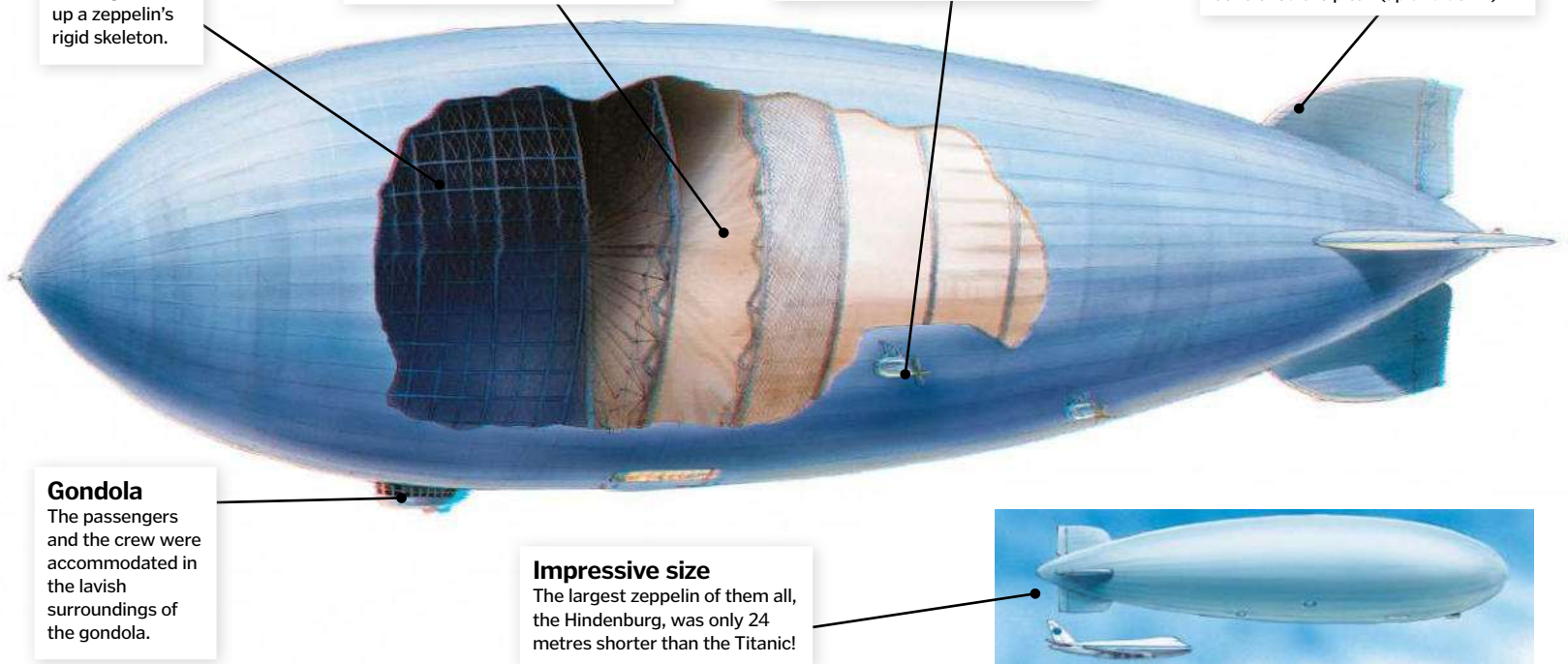
The bags containing the hydrogen were made from sausage skins. The guts of 250,000 cows were used to construct each airship.

Propulsion

Hydrogen was used for lift while blau gas – a gas similar to propane – acted as the engine fuel.

Movement

The airships cruised at speeds of around 125km/h. A rudder managed the yaw (side to side) while elevators controlled the pitch (up and down).



Gondola

The passengers and the crew were accommodated in the lavish surroundings of the gondola.

Impressive size

The largest zeppelin of them all, the Hindenburg, was only 24 metres shorter than the Titanic!

Tipper trucks

Heavy machinery that uses high-pressure hydraulics to dispense material across a construction site

A tipper truck, or dump truck, uses a bed that elevates at high angles to deposit heavy loads. When the driver pulls a handle, oil is pumped from the engine and into hydraulic cylinders. The pistons inside work using Pascal's Principle of fluid mechanics. When force is applied to the cylinder, the pressure on the oil is increased but the fluid won't squeeze into a smaller space, so a piston is forced upwards.

Narrow cylinders exert more pressure so are able to lift massive amounts of

gravel and sand. The powerful upward force raises the truck's bed, sliding the material to the rear of the vehicle. A hinged tailgate at the rear opens up automatically, unloading the building material at the desired location. Some tipper trucks have extra hinges that allow its material to be dropped out at the sides of the bed as well, making the dispensing process that much quicker. A tipper truck's huge wheels help carry the weight and keep the truck balanced when it's navigating the site.

A tipper truck's hydraulic cylinders can telescope to tilt the bed as steep as possible





YOUR SECRET SUPERPOWERS

Quirks of genetics have made some people everyday superheroes

Inside almost every cell in your body are 3 billion letters of genetic code. Hidden among them are around 20,000 genes, which carry the instructions to make proteins. Some form structural scaffolding, like the collagen in our skin. Others are enzymes that drive the chemistry of the body. Some are messengers that transmit signals. And others are involved in the transport or storage of substances in and out of cells and tissues.

When cells divide to make sperm and eggs, all 3 billion letters need to be copied in order to be passed on to the next generation, so mistakes are inevitable. Changes to the genes result in changes to their proteins, and different

mutations have dramatically different effects. Imagine this sentence is a gene: "The quick brown fox jumped over the lazy dog." If you change the 'z' to an 's' (known as a point mutation in genetic terms), you'd still be able to guess the meaning. But if you changed 'f' to 'b', so 'fox' becomes 'box', the message completely changes. This is a 'missense' mutation.

Sometimes, a full stop is accidentally inserted part way through, ie "The quick brown." This is known as a 'nonsense' mutation, and it cuts the protein short. On other occasions, letters are inserted, or deleted, mid-gene. This shifts all of the letters along, changing the way the code is read: "The quixckbrown fox jumped over the lazy dog."

This is known as a frameshift. Parts of genes, or entire genes, can also be duplicated, completely deleted, or crossed together.

Not all of the errors are good, but these mutations are the driving force behind evolution. Many are corrected automatically by the body, some end up being a slight disadvantage, and others can cause very serious genetic faults. But a few can prove to be beneficial, and a rarer few can lead to unexpected superpowers.

"As with all complex genetics, the ACTN3 gene isn't the only factor"

SUPER-SPRINTERS

Sporting talent isn't just down to practice and clean living – some of it is written in our genes

The construction and function of muscles depends on dozens of different genes, but there's one that's caught the eye of sports scientists. It's called ACTN3, and it carries the instructions for a protein called alpha-actinin-3; a molecule involved in high-force contraction of type 2 muscle fibres.

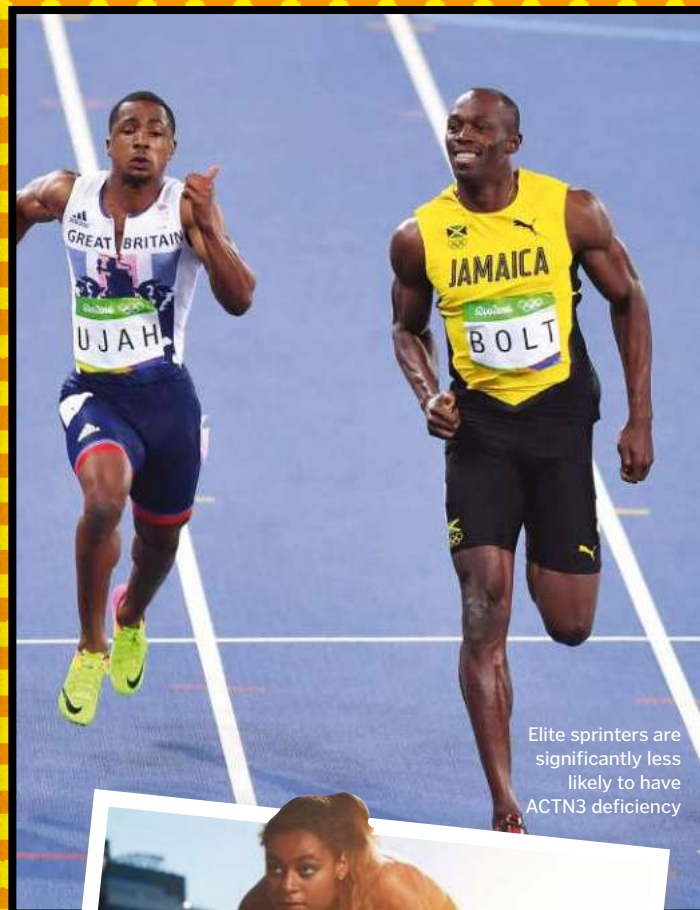
Type 2 fibres, also known as fast-twitch fibres, are used for rapid bursts of movement. They are powerful but they tire easily, and they are critical for sports like sprinting. Type 1, or slow-twitch fibres, in contrast, are better at sustained contraction and endurance. They're not as strong, but they last much longer.

Our muscles naturally have a mix of both, weighted according to what the muscle is mainly used for, but there's variation between individuals in the

number and effectiveness of the different fibre types. Around one-fifth of people of European or Asian descent have a nonsense mutation part way through their ACTN3 gene, cutting the protein short. The result is a deficiency in alpha-actinin-3. This seems to affect how well force is transmitted through muscles, and how type 2 muscle fibres develop in response to training.

As a result, these people don't tend to be able to compete at the highest levels of sprinting. If you look at elite athletes, the proportion of people with the deficiency drops dramatically.

As with all complex genetics, this gene isn't the only factor. Elite male sprinters are more likely to have the deficiency than females, suggesting testosterone might override the disadvantage.



Elite sprinters are significantly less likely to have ACTN3 deficiency

Muscle fibres explained

Muscles contain fast- and slow-twitch fibres for bursts of speed or sustained contraction

Epimysium

The entire muscle is coated in a tough sheath of collagen, which connects to bone via a tendon.

Muscle fibre

Each fibre is a long cell with multiple nuclei and packed with contractile proteins.

Perimysium

Each bundle of muscle fibres is covered by a thin sheath of fibrous collagen.

Fascicle

Between 20-80 muscle fibres are bundled together to form a fascicle.

Type 1

Slow-twitch fibres are thin and red, and packed with stored oxygen for prolonged movement.

Type 2

Fast-twitch fibres are thick and pale. They respond rapidly, but tire quickly.

SUPER SENSES

A quarter of the population can taste something that other people can't

The tongue is covered in bumps that are often, mistakenly, called taste buds. They are actually small mounds of tissue called papillae, and they come in four different varieties. One type can't taste at all, but the others all contain taste buds in their hundreds, or even thousands. These taste buds allow us to sense the five tastes: sweet, sour, salty, bitter and umami.

So called 'supertasters' are able to detect bitter molecules better than everyone else. There are also non-tasters, who are not able to detect certain bitter chemicals at all, and

normal tasters, who are somewhere in between the two.

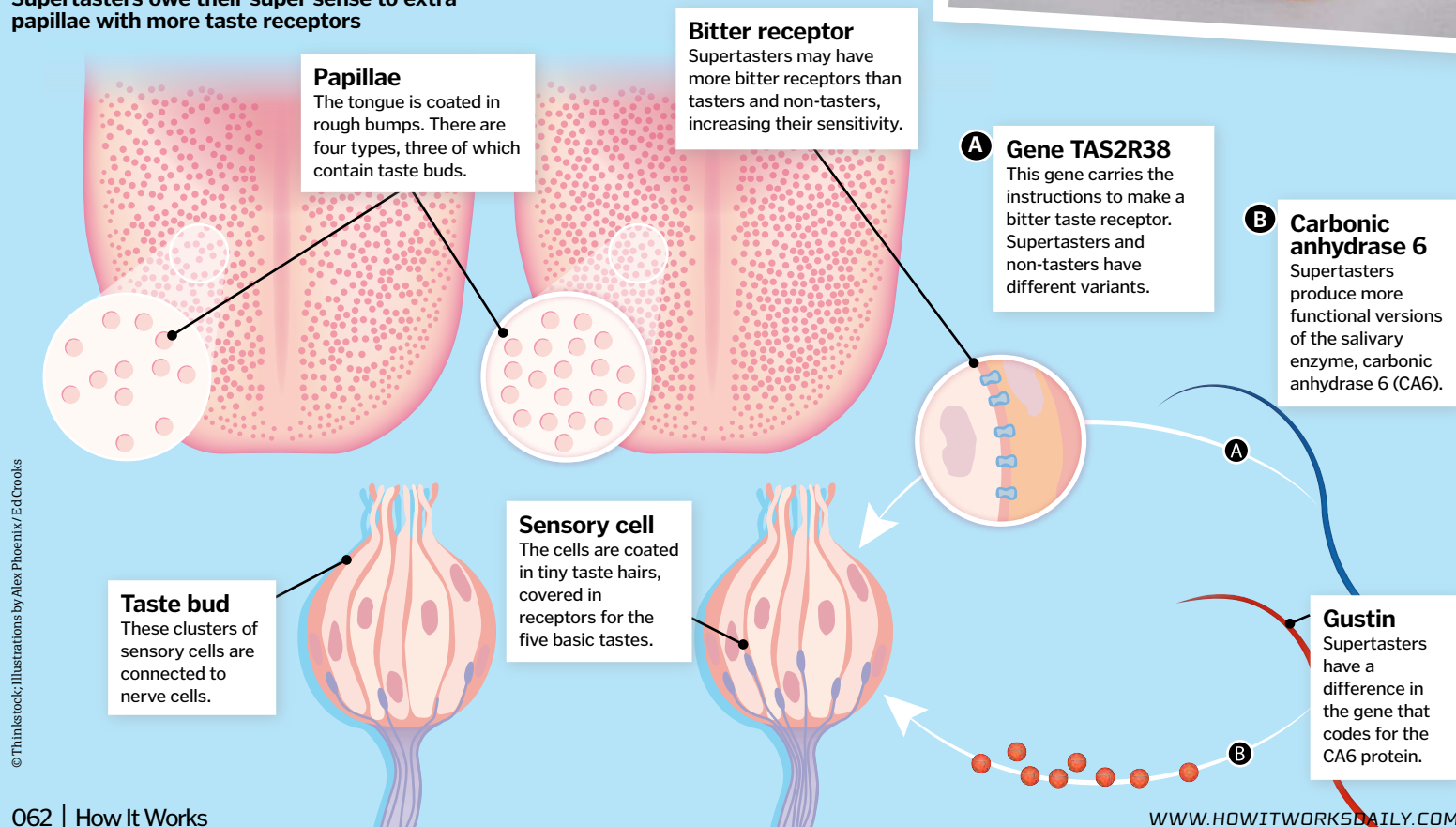
The variation is thought to be down to a couple of mutations in key tongue-related genes. The first is TAS2R38, which codes for a bitter taste receptor (a molecule that picks up bitter chemicals and starts the process of transmitting signals to the brain). The second is gustin, which codes for an enzyme found in the mouth. Thanks to their genes, supertasters end up with more receptors for certain bitter compounds, and a heightened sense of taste.

The best way to find out whether you're a supertaster is to taste a strip of paper coated in a chemical called n-Propylthiouracil, or PROP. To a supertaster, the strips taste intensely bitter, but to a non-taster, they taste of nothing at all. Another low-tech way to find out is to coat your tongue in food colouring and count your papillae – supertasters may have more than others.

"Supertasters are able to detect bitter molecules better than everyone else"

Science of the super tongue

Supertasters owe their super sense to extra papillae with more taste receptors



Short sleepers

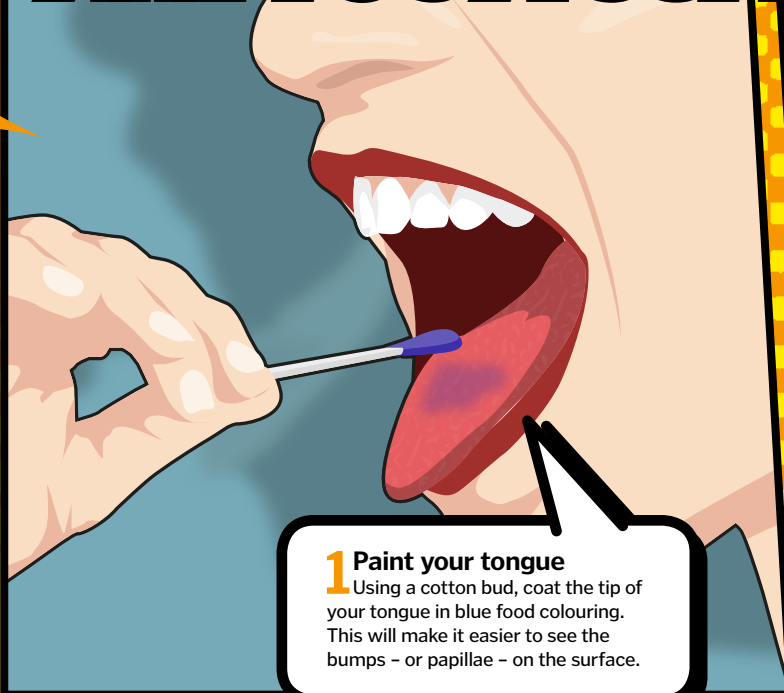
We need sleep to function, but some people need more than others, and that could be down to our genes. Sleep and wakefulness is controlled by an internal clock that sets and maintains a 24-hour cycle known as circadian rhythm (the name is derived from the Latin word *circa*, meaning 'around' and *diem*, meaning 'day'). A key controller of the cycle is a gene called DEC2.

People with a single letter change in their DEC2 gene have a remarkable ability. They average nearly two hours less sleep than the rest of the population without feeling overtired. It's a rare mutation, so scientists turned to mice to study it. They share many of our genes, and like us, need to sleep. When researchers simulated the same mutation in mice, they found that when their whole sleep cycle was shortened, they were still able to keep active for longer. This tiny change seems to add up to a big shift in sleep time.

Mice and humans share many similar genes, including those involved in sleep



ARE YOU A SUPERTASTER?



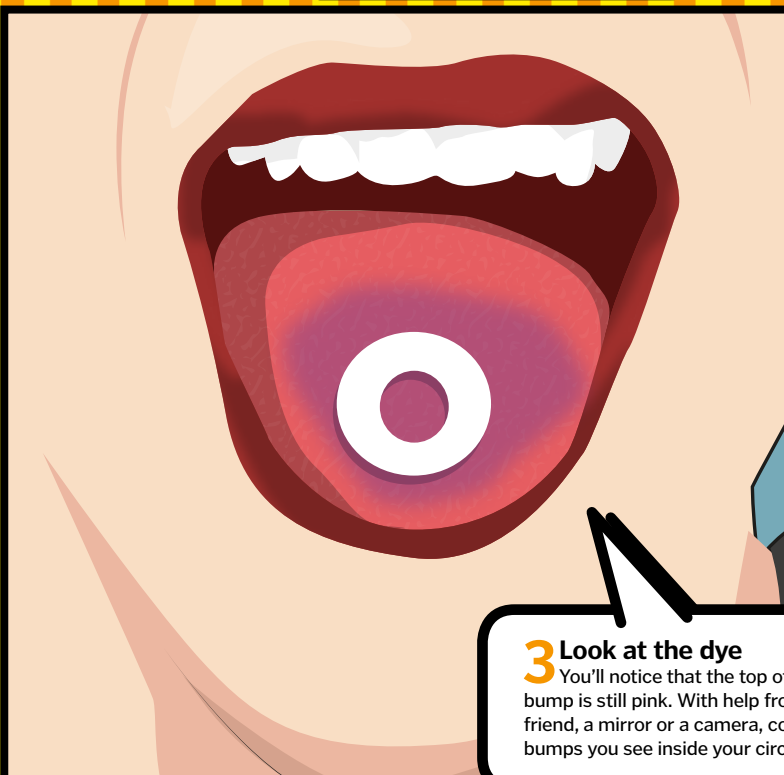
1 Paint your tongue

Using a cotton bud, coat the tip of your tongue in blue food colouring. This will make it easier to see the bumps – or papillae – on the surface.



2 Set your circle

Using a hole punch, make a hole in a small piece of paper and place it over your tongue so that you can see a round section of blue.



3 Look at the dye

You'll notice that the top of each bump is still pink. With help from a friend, a mirror or a camera, count the bumps you see inside your circle.



4 Count the bumps

If you have fewer than 15 bumps, you are probably a non-taster. More than 35, you're likely to be a supertaster, and somewhere in between, you're a normal taster.

Variations in the 5-HTT gene affect serotonin signalling in the brain



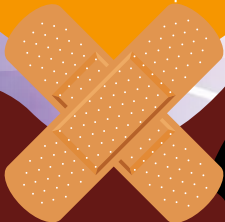
Depression resistance

Serotonin is sometimes known as the happiness hormone. It's a neurotransmitter produced in the brain and is used by nerve cells to communicate. We all have it, but small genetic changes seem to alter the way it affects us. 5-HTT is the serotonin transporter. Its job is to clear leftover serotonin out of the space between nerve cells after the signal has been sent. And 5-HTTLPR is a part of its gene.

It contains lots of repeated sections of genetic code, and people tend to have one of two variants: a short version with 14 repeats, or a long version with 16. People with the short version seem to have an increased likelihood of depression when they are exposed to major life stresses, while people with the longer version seem to be more resistant.

Pain relief

Some people have mutation in the gene SCN9A, which makes part of a molecule found in pain-sensing nerve cells. Without this piece, the nerve cells aren't able to transmit electrical signals properly, making it almost impossible to feel pain. Targeting this mutation could help develop treatments for those with chronic pain.



Bone repair

Sclerosing bone dysplasias are a group of disorders that affect the way that minerals are laid down in bone. In some people, the bones can become so hard that they damage the tools of surgeons trying to treat them. Studying these conditions could help figure out ways to help patients with bone diseases like osteoporosis.



Heart protection

The PCSK9 protein is involved in controlling the level of LDL-c cholesterol in the blood. It's sometimes known as 'bad cholesterol', and is linked to atherosclerosis and heart disease. Some people have a mutation in the PCSK9 gene, and are able to keep their blood cholesterol lower.



HIV

HIV resistance

HIV needs to get inside cells to survive. It does this by hijacking a molecule called CCR5, which is found on immune cells. Different people have different amounts of CCR5 on their cells, and some people have no CCR5 at all, giving them natural resistance to the infection.



Understanding these genetic mutations could lead to new ways to treat disease

"Brain-boosting mutations also benefitted our cousins, the Neanderthals"

Poison resistance

Arsenic is a deadly poison. It can cause cancer, heart disease and lung problems. But the residents of San Antonio de los Cobres in Argentina have a secret weapon. The water from their local hills is contaminated, sometimes containing up to 20 times more arsenic than the maximum level recommended by the World Health Organization. Fortunately, thanks to a genetic mutation, they are able to resist its effects.

When arsenic enters the body, it is first changed into a compound called monomethylarsonic acid (MMA) and then into a compound called dimethylarsinic acid (DMA). This is done by molecules called methyltransferases. MMA is the most toxic, and this is where the people in San Antonio de los Cobres have an advantage. They have alterations in the genes that code for arsenite methyltransferase (AS3MT), allowing them to quickly break it down into DMA, therefore shielding their bodies from the worst of the effects.

The water in San Antonio de los Cobres contains dangerous levels of arsenic



Small genetic changes set us apart from our closest living relatives



Unexplained superpowers

RAPID REFLEXES

Japanese laido master, Isao Machii, can cut a speeding BB gun pellet in half using a samurai sword.

PHOTOGRAPHIC MEMORY

Stephen Wiltshire can memorise and redraw a cityscape after only a few minutes observing it.

SUPER SIGHT

Veronica Seider claimed to have been able to identify a person from over a mile (1.6 kilometres) away.

NUMERICAL MASTERY

Daniel Tammet is able to memorise enormous strings of numbers, once reciting pi to 22,514 decimal places.

SEEING DIFFERENTLY

Daniel Kish lost his eyesight as a child, but can 'see' with his ears using clicks for echolocation.

MADE OF MUTATIONS

We are who we are thanks to a series of genetic mutations

Our genes are 98.8 per cent the same as the genes of a chimpanzee. Although that difference might sound small, in a sequence of 3 billion letters, it equates to a lot of code.

We share a common ancestor with the other great apes. Around 10-15 million years ago, chimps, gorillas and humans didn't exist. In our place was our shared primate ancestor, who contained an important gene called RNF213.

The function of this gene is not fully understood, but a mutation found in modern humans leads to a narrowing of the carotid artery. This major vessel supplies blood to the head, and changes in the gene when our ancient ancestor was alive are thought to have helped improve blood supply to the growing brains of great apes. But the other apes didn't develop human-like intelligence. More genes have contributed to the development of our cognitive abilities as time has gone by.

An area of the genome called Human accelerated region 1 (HAR1) evolved quickly after the ancestors of humans and chimpanzees parted ways between 5-7 million years ago. It's expressed in neocortex; the most recently evolved part of the brain. In chimps, the molecule made using the HAR1 code is a disorganised structure, but in humans it looks like a clover. This more orderly orientation alters the expression of other genes, changing the way that our brains develop.

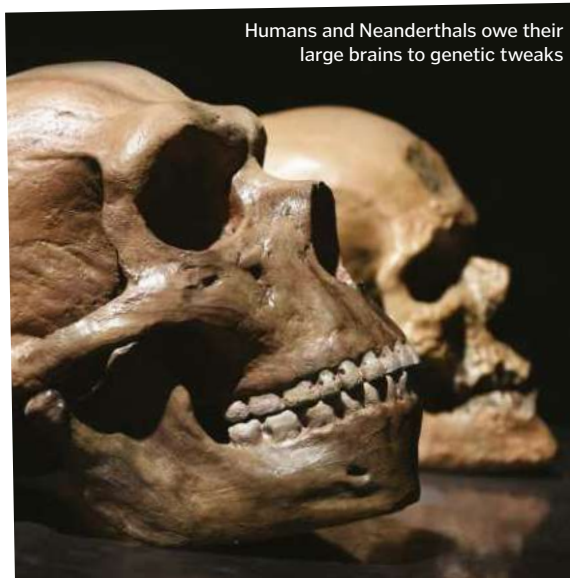
Our ancestors also ended up with a duplication of a gene called SRGAP2, which allowed the nerve cells in the neocortex to make stronger connections. Changes later accumulated in a gene called FOXP2,

which aids language learning by helping us to convert our declarative memory (memory of facts and events) into procedural or habitual memory (the long-term unconscious memory that allows us to perform tasks).

All three of these brain-boosting mutations also benefitted our close relatives, the Neanderthals. But after our ancestors diverged around 500,000-600,000 years ago, more genetic changes continued to give us homo sapiens the edge. One was an edit in a gene called AHR, which helped to shield us from the toxic effects of smoky fires, and another was the duplication of a gene called AMY1, which codes for amylase, an enzyme that helps to break down carbohydrates inside the food we eat.

Over time, these little genetic tweaks have allowed us to adapt to our changing environments, all adding up to make us the planet's dominant species.

Humans and Neanderthals owe their large brains to genetic tweaks



Fresh bread smell

What creates the aroma of a loaf straight out of the oven?

The mouth-watering smell of freshly baked bread is created by a complex cocktail of chemical compounds produced during the bread-making process. The ingredients used are a source of some of these compounds, but raw dough doesn't smell particularly delicious, so other factors are needed to develop the aroma.

Byproducts of the fermentation process, when yeast converts sugars into carbon dioxide, produce many of the main aroma compounds of the bread's crumb, while the smell and deep brown colour of the crust are created inside the

oven. During baking, Maillard reactions between the sugars and amino acids, and caramelisation reactions of the sugar, contribute the final components of the breads flavour and odour. The ratio of ingredients, length of fermentation and temperature of baking all influence the amount of each compound that is created, causing each type of bread to have its own unique aroma.



Some companies sell diffusers and sprays that smell of fresh bread

Freshly baked chemistry

Discover some of the compounds that contribute to bread's delicious aroma

(E)-2-nonenal

Produced in the crust, this compound also contributes to the odour of cucumbers.

Maltol and isomaltol

These compounds are created as a result of the caramelisation of sugars in the crust and add a sweet aroma.

2-acetyl-1-pyrroline

Formed during baking, this compound produces the roasted, cracker-like smell of the crust of wheat bread.

Methional

Found in high levels in the crust and crumb of rye bread, this compound imparts a potato-like scent.

2,3-butanedione

More commonly known as diacetyl, this compound creates the buttery smell of the bread crumb.

Incense

Can burning incense be bad for your health?

People have been burning incense for centuries, whether as part of religious practices or for its pleasant smell. There are two main types: indirect-burning and direct-burning incense, but the latter is more common.

Indirect-burning incense requires a separate heat source, such as charcoal, to burn aromatic ingredients like sandalwood and agarwood, while direct-burning incense comes as a stick with aromatic ingredients adhered to it and burns by itself. These sticks are typically made of bamboo soaked in an adhesive material such as tree resin and coated with herbal and wood

powder and fragrance materials. They are used in temples and homes throughout the world, but a recent study has found that they can also be hazardous for your health.

Burning incense releases particle matter into the air, which can then be breathed in and trapped in the lungs. Some of these particles have been found to be highly toxic and contain chemical properties that have been linked to the development of cancers. Therefore, it is advised that burning incense should be done outdoors or in a well ventilated room to reduce exposure and thereby lessen any potential health risks.



Incense burns at a slow and even pace to produce aromatic smoke



Newton's Laws of Motion

THREE SIMPLE LAWS EXPLAIN THE EFFECT OF FORCES ON THE UNIVERSE AROUND US

BACKGROUND

Isaac Newton's famous Laws of Motion explain what happens to objects when forces are applied. A force is a push or a pull, like gravity, friction or magnetism. They can't be seen directly, but their effects can be measured; they can change the speed, shape or direction of movement of an object, and they are responsible for pressure and weight. Newton's three laws describe what happens when forces are balanced or unbalanced, and explain the idea of equal and opposite forces.

IN BRIEF

Newton's First Law explains what happens if the forces acting on an object are balanced. If an object is not moving, it won't start moving. And, if an object is already moving, it won't stop. This tendency is known as inertia.

Newton's Second Law describes what happens if the forces acting on an object are unbalanced. If more force is applied in one direction, the object will accelerate. The more unbalanced the forces, the faster the object will accelerate. The more massive the object, the more force that is needed to make it move.

Newton's Third Law explains that for every action there is an equal and opposite reaction. Forces come in pairs; if one object exerts a force on another, the first object will exert an equal force in return. A simple example is the recoil of a gun; as the bullet flies forwards, the gun kicks back.

Newton's laws first appeared in his masterpiece, *Principia*, in 1687, and he developed them to explain why the orbits of the planets are ellipses, not circles.

SUMMARY

Newton's First Law describes what happens when forces are balanced. His Second Law describes what happens when they are unbalanced. The Third Law explains forces acting in equal and opposite pairs.

Newton's Laws in action

The Laws of Motion govern the movement of everything around us

First Law

The forces acting on the stationary rocket are balanced. The downward pull of gravity is matched by the upward push of the ground.

Air resistance

A frictional force acts on the rocket as it moves through the air.

Second Law

As the engines fire, the force of the thrust is greater than the force of gravity. They become unbalanced and the rocket accelerates.

Applied force

The exhaust from the engine applies a force beneath the rocket.

Gravity

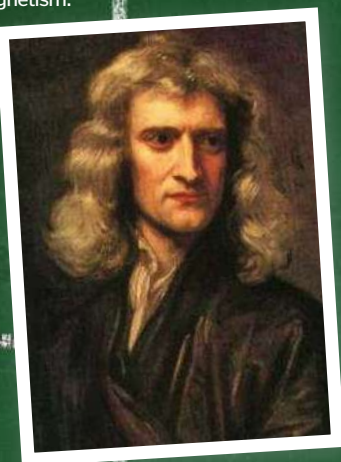
Objects with mass are attracted to one another by the force of gravity.

Normal force

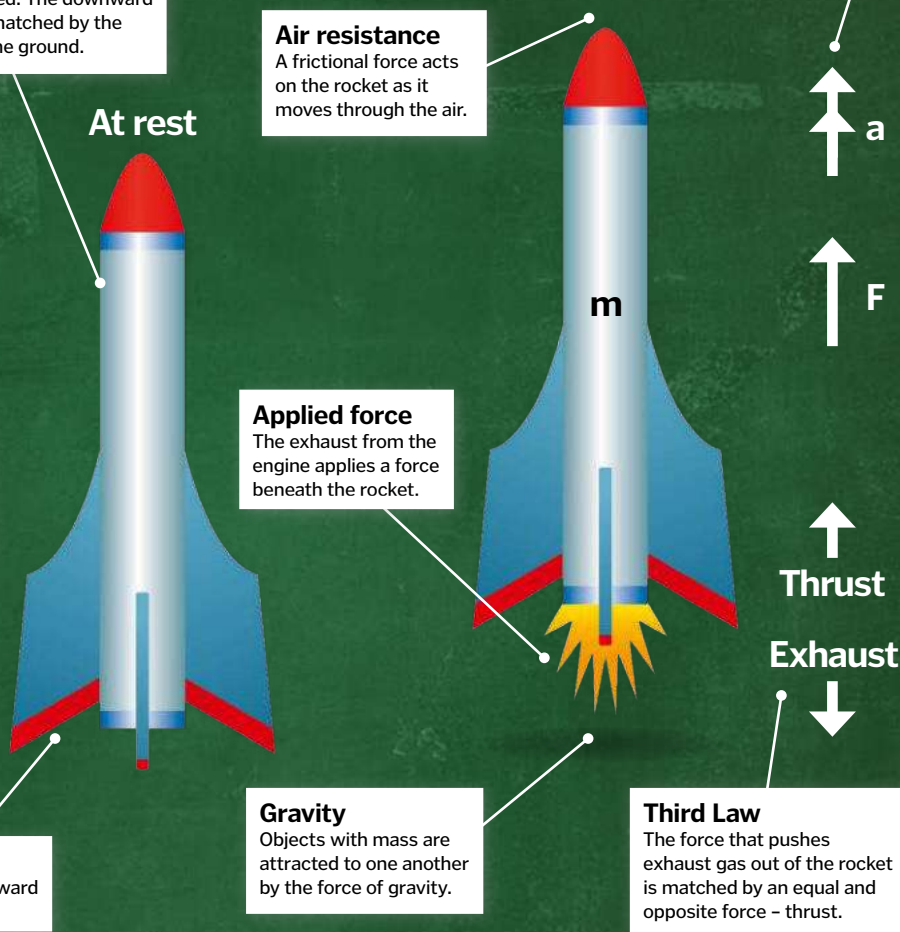
The Earth exerts an upward force on the rocket.

Third Law

The force that pushes exhaust gas out of the rocket is matched by an equal and opposite force – thrust.



A portrait of a 46-year-old Isaac Newton, painted in 1689



THE MAN BEHIND THE LAWS

SIR ISAAC NEWTON WAS A MATHEMATICIAN, PHYSICIST AND ASTRONOMER, BORN ON CHRISTMAS DAY IN 1642 (ACCORDING TO THE OLD JULIAN CALENDAR). HE DESCRIBED THE MECHANICS OF THE UNIVERSE WITH MATHS AND EQUATIONS IN HIS BOOK, THE *PHILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA* (COMMONLY KNOWN AS *PRINCIPIA*). HE EXPLAINED THE CONCEPT OF GRAVITY, AND SHOWED THAT EVERYTHING IN THE UNIVERSE IS GOVERNED BY THE SAME PHYSICAL LAWS. HE ALSO WORKED ON

COLOUR THEORY, OPTICS AND CALCULUS, AND HIS IDEAS ARE STILL IN USE OVER 300 YEARS LATER.

HE WAS ONE OF THE GREATEST SCIENTISTS EVER TO HAVE LIVED, BUT HIS ACHIEVEMENTS DIDN'T STOP THERE. HE BUILT THE FIRST PRACTICAL REFLECTING TELESCOPE AND WAS ELECTED AS A MEMBER OF PARLIAMENT. HE EVEN BECAME MASTER OF THE ROYAL MINT, IN CHARGE OF THE PRODUCTION OF ALL OF BRITAIN'S CURRENCY FROM 1699 UNTIL HIS DEATH IN 1727.



Cosmetic chemistry

Lotions and potions are packed with chemical science, but do they live up to the hype?

Mattifying makeup

Mattifying makeup products attempt to minimise shine by including ingredients that absorb oil and water. Clays are made from oxygen or oxygen and hydrogen (hydroxyl groups) and arranged into crystals with four or eight sides. At the centre of each is an atom of silicon or aluminium. These structures form sheets, and it's between these sheets that oil and water become trapped. Mattifying agents can be found in a variety of products, including powders, foundations, lotions, balms, gels and sprays.

Silicone elastomers are a synthetic alternative. They are made from chains of silicone, carbon, hydrogen and oxygen strung together to form branching webs. These expand when liquids are added, helping to lock moisture away.

Anti-wrinkle creams

Proteins are the major building blocks of the human body and collagen and elastin are two critical types found in skin. They form a web-like scaffold that holds skin cells in place; collagen provides structure and elastin provides springiness. However, as we get older, we produce less and less of both, and skin starts to lose its firm, flexible texture.

One solution employed by cosmetics giants is to add fragments of protein to their creams. This helps to smooth out wrinkles, but probably not in the way you were expecting. Rather than repairing the collagen and elastin scaffolding, the fragments work by improving skin texture from the outside. They go on damp and flexible, and as they dry out they tighten up. This tugs on the skin beneath, temporarily smoothing out the wrinkles.

"Exfoliating washes contain fragments of sugar, nut shells or plastic that act as abrasives"

Whitening toothpaste

Whitening toothpastes work like a rough polish, using abrasive grains to scrape away the film of bacteria and pigments that continually builds on the surface of the enamel. However, they can't change the colour of the teeth beneath. For teeth whiter than a natural shade, chemical bleaching is the only option. Whitening strips contain carbamide peroxide, which breaks down chromophores, the parts of molecules responsible for their colour.

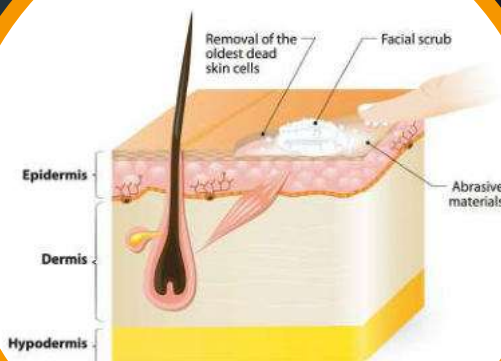
Waterproof mascara

Mascara colours the eyelashes using pigments like carbon black (made by the incomplete burning of petrochemicals) and iron oxides (which come in varying shades of red and brown). For ease of application, they are suspended in oils, waxes and water, forming a paste that can be spread onto the lashes with a brush. These carriers include beeswax, shellac (a type of resin made by lac bugs), lanolin (from sheep) and paraffin.

Waterproof mascaras tend to contain more waxes and oils than their water soluble counterparts, helping them to resist moisture and stay on the lashes longer. But, because they've been designed not to dissolve in water, they can be a challenge to wash off. Oily makeup removers help to dissolve the waxy carriers that stick the pigments to the lashes. The mascaras themselves sometimes contain lubricants, like glyceryl stearate, which help the mixture to stay slippery.

Exfoliators

The skin is in a constant state of renewal, and as new skin cells are made, the old ones flake away. Exfoliators help to rub these from the surface, making the skin look smoother and brighter. The textured surface of a washcloth is enough to gently scrub away some of the surface cells, but many treatments offer a deeper cleanse. Exfoliating washes contain tiny fragments of sugar, crushed nut shells or plastic that act as abrasives. Chemical peels use acids (commonly salicylic or lactic acid) to create a controlled burn, and microdermabrasion uses a rough rotating brush to scrape away even more of the skin's surface.



Shimmery shadows

The glitter and sheen in eyeshadows and highlighters is most commonly mica or bismuth oxychloride. Mica bends the light as it hits, while bismuth oxychloride has a pearlescent appearance. If mica is combined with titanium dioxide the way it reflects light changes, creating iridescent shades.

Makeup primers

Primers contain lots of ingredients that aim to keep makeup looking fresh all day. Silicones help to absorb moisture and oils, while waxes and polymers form a bridge that sticks cosmetics to the skin. Spherical silicone molecules coated with titanium dioxide help to diffuse light, evening out blemishes and creating an 'airbrushed' look.



Cosmetic myths

1 Bypassing the barrier

Creams might contain vitamins, proteins or even DNA and be accompanied by claims that the molecules will repair the tissue underneath. But skin is a barrier; not everything can get through.

2 Stretch mark miracles

Hydrated skin hides blemishes better than dry skin, but stretch marks are scars, so no amount of moisturiser is truly going to remove them.

3 Hot water opens pores

Pores don't open and close, and you can't do anything to change their size. However, warm water can help to loosen anything that might be stuck inside your pores.

4 'Clinically proven'

Be wary of cosmetic science claims. Studies can be small or involve experiments using raw ingredients in test tubes, not the actual product on real people.

How perms work

The secret to perfect curls is some simple hair chemistry

A perm, or permanent wave, is a style created by exploiting your hair's chemistry. Hair is made from flat, overlapping cells covering a core of fibres. These fibres are made from a protein called keratin.

Keratin is made from small units, woven together into two-stranded coils. Four of these coils are in turn coiled together, and these are joined end-to-end to make structures called protofilaments. Eight protofilaments wind up to make up intermediate filaments, which clump together to make macrofilaments, which are glued into strands by the fatty membranes of spindle-shaped cells. It's these structures that are key to curls.

The keratin molecules contain a component called cysteine. It's an amino acid – one of the building blocks of protein – and it contains sulphur. A sulphur from one cysteine can form a strong bond to a sulphur from another cysteine, which means that neighbouring keratin molecules can become linked together. Depending on where these tiny links are made, they could hold the hair poker straight or twist it into ringlets.

Cold perms use a chemical called ammonium thioglycolate to break the bonds so that the hairs can be twisted into a new shape. Then hydrogen peroxide is added to allow new bonds to form between the strands, setting the curl.

Rollers help to set the hair into its new shape



Psychological triggers

Sensory and emotional triggers, like motion or fear, can set off the vomit reflex.

Muscle contraction

The diaphragm and abdominal muscles contract, helping the contents of the stomach to move into the oesophagus.

Openings

The pyloric sphincter at the bottom of the stomach relaxes to allow content to enter from the gut.

The vomit reflex

Being sick is controlled by a tiny part of the brainstem

Vomiting centre

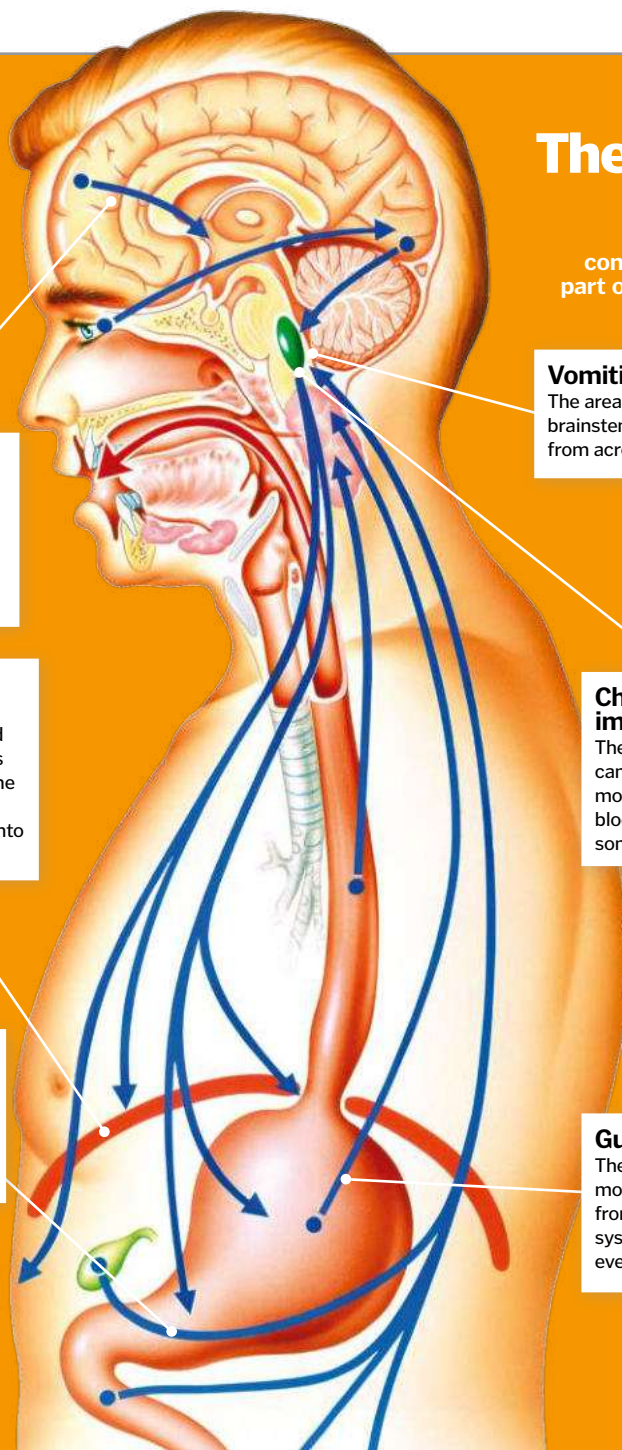
The area postrema in the brainstem receives signals from across the body.

Chemical imbalance

The vomiting centre can be triggered by molecules in the blood, including some medications.

Gut signals

The vomiting centre monitors signals from the digestive system to check that everything is normal.



What makes us sick?

Nobody likes to throw up, but it's an ancient reflex that protects us against poisoning

The vomit reflex is hard-wired. It's controlled by the brainstem, one of the most primitive parts of the brain, from a spot known as the area postrema, or vomiting centre. The centre receives information from across the digestive system, from parts of the brain involved in processing sight, smell, balance and emotion, and from the chemoreceptor trigger zone, which detects toxins in the blood.

If something isn't right, the area postrema sets off a tightly coordinated reflex. The mouth

fills with saliva, shielding the teeth from the effects of stomach acid. The body takes a deep breath before access to the lungs is blocked off. The soft palate in the mouth is raised to cover the nostrils.

The diaphragm then contracts downwards sharply, lowering the pressure in the chest. The top of the small intestine squeezes in reverse, and the abdominal muscles crunch inwards. The contents of the stomach are squashed up into the oesophagus, and out through the mouth.

How wounds heal

It takes an army of cells to repair cuts and scrapes

Wound healing happens in four key stages: haemostasis, inflammation, proliferation and remodelling.

Haemostasis means 'blood halting' in Greek, and is the first crucial part in closing a wound. The body's first line of defence is to constrict the blood vessels in the affected area to minimise blood loss. Platelets then start to stick to the exposed tissue, becoming activated and encouraging more and more platelets to clump together to plug the gap.

Once this plug is in place, a mesh of fibrin fibres starts to form around it, trapping passing

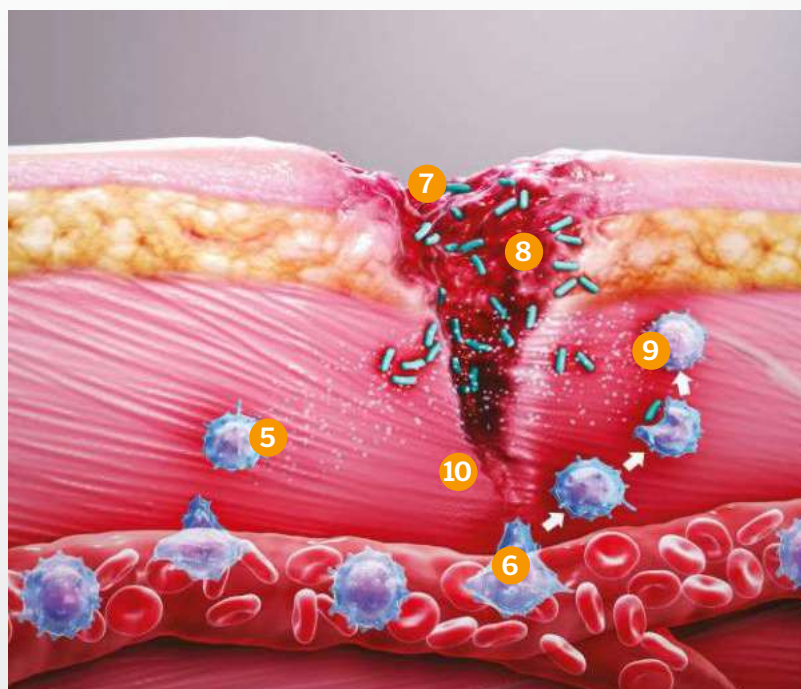
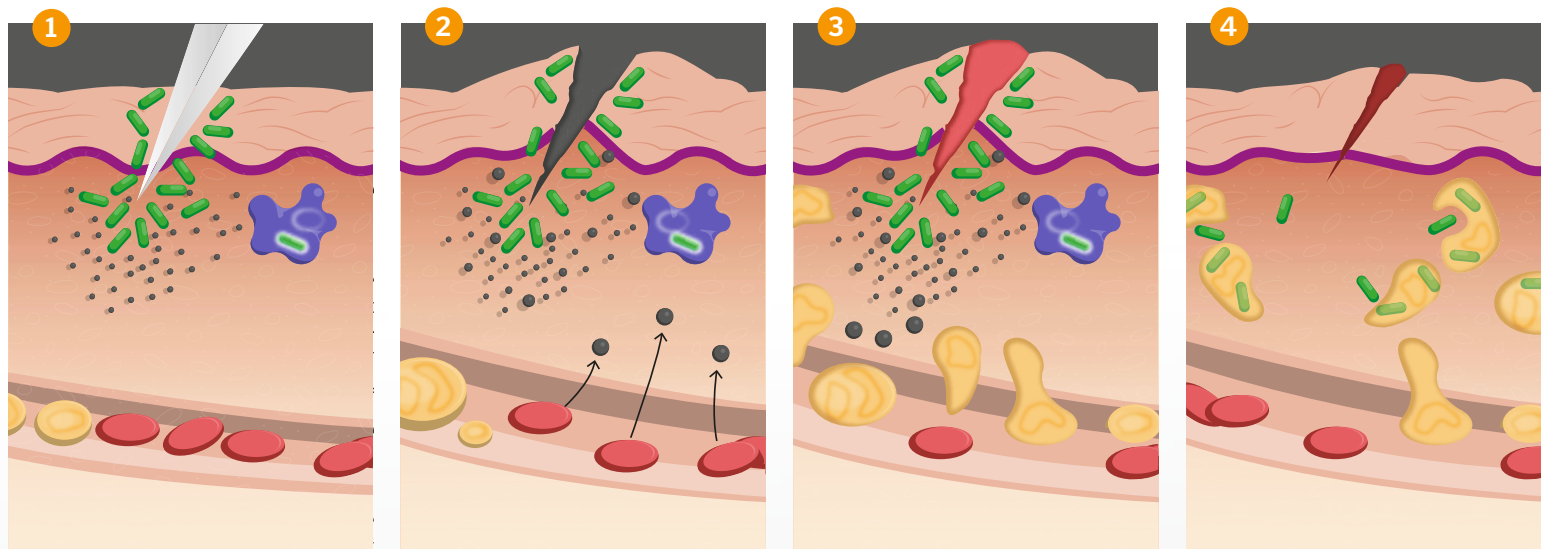
blood cells and forming a sturdy clot that holds the wound closed until it can be repaired. This process only takes a matter of minutes, and once the bleeding stops, the local blood vessels dilate again, allowing immune cells to reach the area and begin the necessary repairs. This stage is called inflammation.

White blood cells clear up dead cells, get rid of damaged tissue and chase down any pathogens that have entered through the wound and destroy them by phagocytosis (ingesting them). They also prepare the area for the repair phase, which is known as proliferation.

With the encouragement of the immune system, long, spindle-shaped cells called fibroblasts start rebuilding the collagen scaffolding that holds healthy tissue together. On top of the wound, epithelial cells begin dividing and migrating to cover the gap. New blood vessels start to form and, as the tissue heals, myofibroblasts tug at the edges of the wound to close the hole. Once this stage is complete, it's time for remodelling. The scaffolding built by the fibroblasts is rearranged, and any unneeded cells that were made during the healing process are safely removed.

Halting infection

The immune system rushes in to prevent pathogens entering through an open wound



1. Injury

Blood vessels in the local area instantly constrict, reducing blood loss and limiting the chances of anything entering the bloodstream.

3. Immune response

Immune cells flood into the area, chasing down and killing any bacteria and cleaning away dead cells and damaged tissue.

5. Macrophage

Macrophage means 'big eater'. These cells are responsible for clearing away pathogens and debris.

7. Granulation

New tissue starts to form at the site of the injury, disordered at first before gradually becoming orderly.

9. Following the trails

Immune cells are attracted to the site of the wound by a trail of chemical signals.

2. Clotting

A plug of platelets starts to form. Clotting factors transform it into a strong network of fibres and trapped blood cells, barricading the breach.

4. Repair

Immune cells encourage other cells to begin repairs. The support network under the skin is regenerated, and new cells grow over the wound.

6. Immune arrival

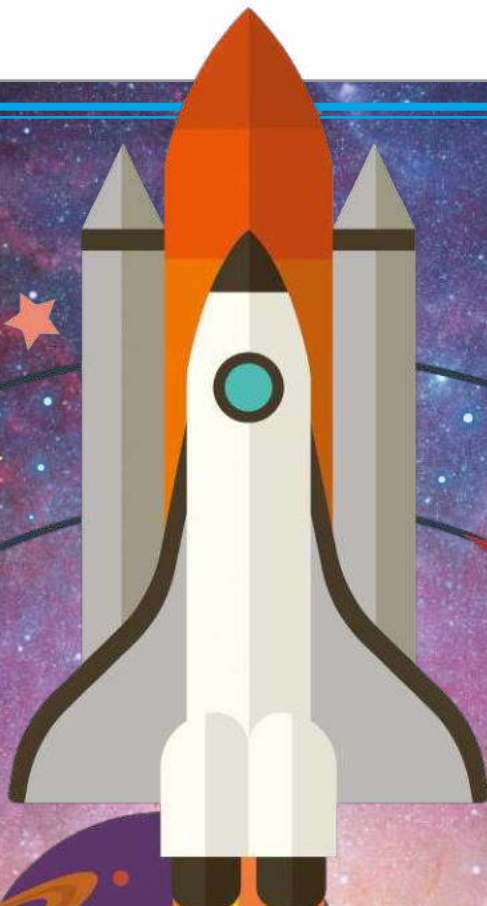
Immune cells squeeze out of the blood vessels and into the tissue in a process called extravasation.

8. Bacteria

An open wound allows pathogens like bacteria to get inside the body.

10. Scarring

If the dermis (deep layer of skin) has been damaged, new collagen fibres form to mend it, creating a scar.



COSMIC MYSTERIES

From the edge of space to alien life, what are some of the biggest unknowns in the universe?

What's at the edge of the universe?

Strange as it may sound, there's technically no edge

Our universe is constantly expanding and, based on observations in the last two decades, we think it's getting faster and faster. That begs the question: what's it expanding into, and what is at the edge?

Well, that's where things get a bit tricky. Technically, there is no edge of the universe. From our galaxy, we can see a finite distance (about 46 billion light years), which is the most distant light that has travelled to us since the Big Bang. We call this the observable universe, meaning it spans about 92 billion light years in total. But beyond this barrier, there may well be more space, more galaxies, more stars and more planets. Unfortunately, because light has a finite speed, we will never see beyond this limit.

As the universe is expanding, that means galaxies are also getting further and further away from each other. A common analogy is imagining each galaxy as a dot on an expanding balloon. From our position, it looks like all the galaxies are moving away from us. But if you were in any other galaxy, even the most distant one we could see, you would notice the same effect. There is no edge of the universe – space itself is just simply expanding. And it's not expanding into anything, it's just growing.

That's quite hard to fathom; there's no easy way to wrap your head around it. That's why it truly is a bit of a cosmic mystery.

Over the edge
It's thought the oldest photons we can see have been emitted from objects 45-47 billion light years away.



"The universe is not expanding into anything, it's just growing"

An expanding universe

Everything is moving away from everything else in the cosmos

Galaxies
Other galaxies would observe the same expansion effect that we see on Earth.

Expansion
Space itself is rapidly expanding, but it is not expanding into anything.

Local groups
Some galaxies in localised groups move towards each other due to gravity.

Earth
From our perspective, it looks like most other galaxies are moving away from us.

Lumpy
The distribution of matter – and thus gravity – in the universe is irregular.

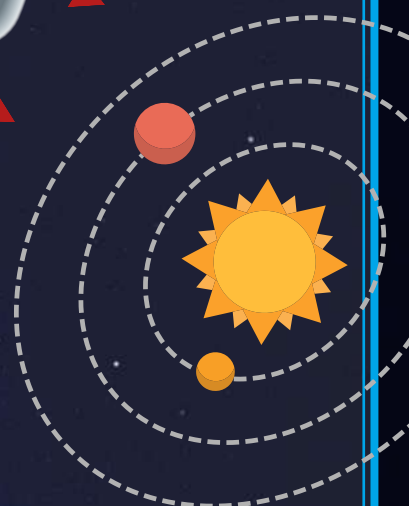
No edge
There is no edge to the universe, although that does not mean it's infinite.

Studying the edge

The most distant galaxy we've ever seen is GN-z11. The light from this bright infant galaxy shows it as it appeared 13.4 billion years ago, just 400 million years after the Big Bang. We measure galaxies at the edge by observing their redshift, which is the change in their light as they move away from us. However, this is not technically the furthest thing we can see. We can actually see remnants of the universe as it appeared 380,000 years after the Big Bang. Known as cosmic microwave background (CMB) radiation, this is the heat left over from when the universe went through a period of rapid expansion and then cooled.



This is the Hubble Space Telescope's view of the galaxy GN-z11.



Is the universe a hologram?

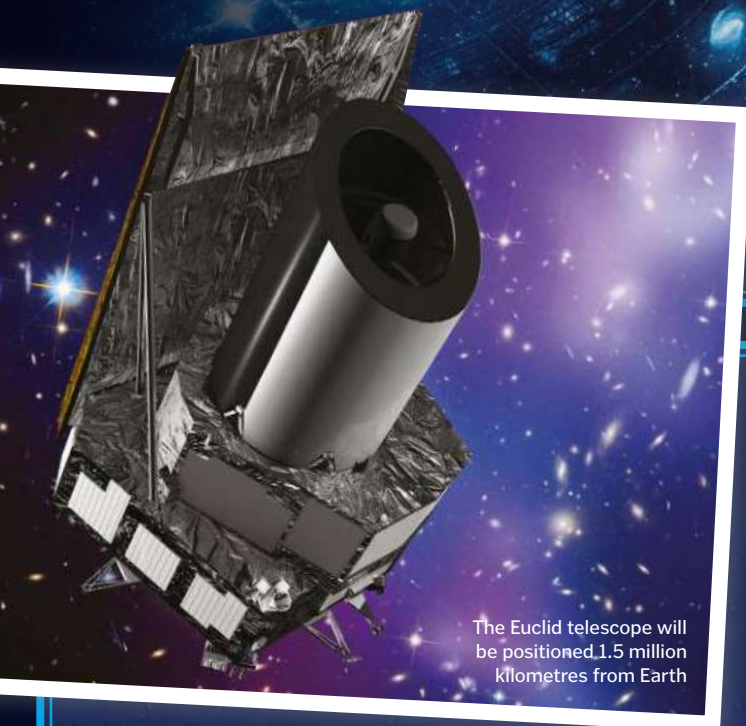
Startling theories suggest we're a projection on a 2D plane

It sounds a bit bizarre – an idea that our three-dimensional universe might be a projection on two-dimensional space. And it is bizarre. But the theory has some supporters, and we still don't know if it's true or not.

The idea is based on the holographic principle, which is an attempt to bring together quantum theory and gravity. It suggests that the entire universe appears as nothing more than a projection on the cosmological horizon, including us. We are a three-dimensional projection on the true universe, which is a two-dimensional plane, according to the theory. The idea comes from string theory, which says that gravity is made up of thin, vibrating strings. These might contain information about 3D objects, meaning there's no reason to have a 3D universe at all.

Unfortunately, we have no way of knowing for sure if this is true or not. To us, a holographic universe and a regular universe would look identical. The best chance we have of knowing will come from experiments at a quantum level, but we may never know if we really are just a hologram or not. The idea of a holographic universe is also somewhat controversial.

Is our three-dimensional universe just a projection?



The Euclid telescope will be positioned 1.5 million kilometres from Earth

"According to the theory, we're a 3D projection"



Dark matter and dark energy

Most of our universe is 'missing'. It's estimated that only five per cent of the universe is normal matter (things like galaxies, stars and planets) and the rest is invisible matter and energy. The invisible matter is thought to be dark matter, which emits no visible light and thus can only be detected by seeing its effect on galaxies. We think dark matter makes up about 27 per cent of the universe, but we are yet to make a direct detection of it.

Dark energy is similarly named, but very different. In 1997, we discovered that the universe was expanding at an accelerating rate, causing scientists to suggest there may be an undetectable force permeating through space: dark energy. This is thought to make up a whopping 68 per cent of the universe. ESA's Euclid mission, set to launch in 2020, will aim to investigate dark matter and dark energy by measuring the motion of galaxies 10 billion years into the past.

What reionised the universe?

This strange period allowed things to become visible in the cosmos

Reionisation refers to a time when the universe went from being opaque to transparent, the cause of which we're still not sure about.

After the Big Bang, the universe was a bit like a hot soup of particles, until it cooled down enough for neutral hydrogen atoms to form after about 380,000 years. Light was absorbed by the hydrogen atoms, making the universe opaque until after around 1 billion years, when the hydrogen was ionised – it

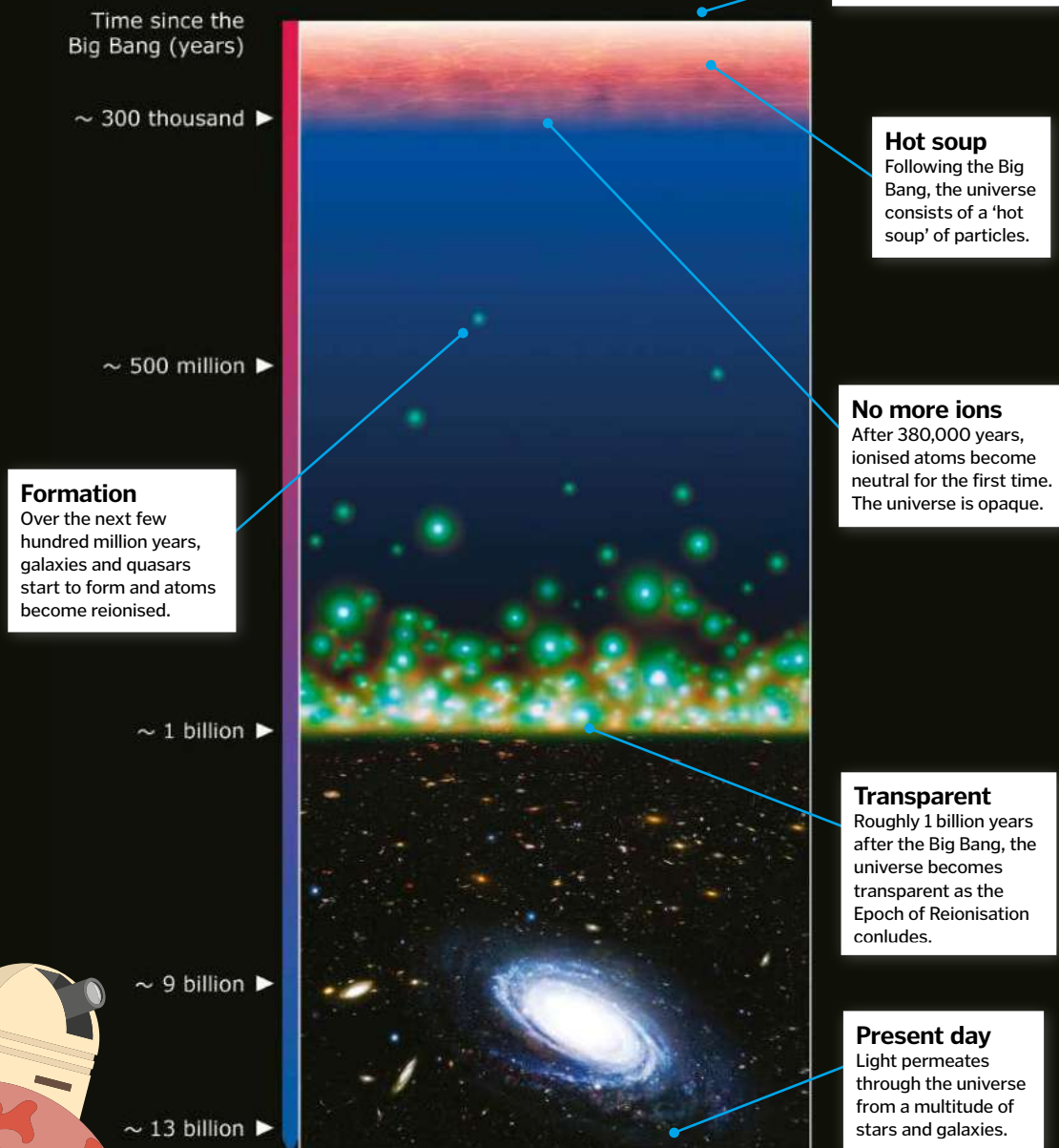
gained and lost electrons – and the universe became transparent.

What caused this period, known as the Epoch of Reionisation, isn't clear. Some think the formation of the first stars may have provided the energy for this to occur. Upcoming missions like NASA's James Webb Space Telescope (JWST), due to launch in October 2018, will seek to provide an answer.

JWST will hope to unlock many secrets of the universe

Epoch of Reionisation

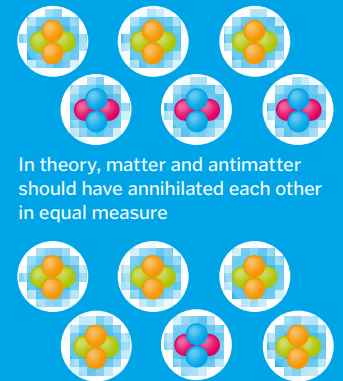
A brief history of the cosmos from the Big Bang to now



Where is all the antimatter?

According to our theories, the Big Bang should have created equal amounts of matter and antimatter, which have the same mass, but opposite electric charge, and thus destroy each other. But matter is clearly dominant in the universe, so where is the antimatter? This is called the matter-antimatter asymmetry problem, or baryonic asymmetry (baryons being regular matter). Matter and antimatter should have annihilated each other in the early universe, but something must have tipped the balance in favour of the former.

While we don't know for certain, it's probable that there was some sort of imbalance in the early universe that accounts for the difference. Some theories even predict there could be regions of the universe where antimatter reigns supreme. That's unlikely, but we don't yet have a clear answer to this problem. Institutions like CERN are looking for an answer by observing the behaviour of matter and antimatter in high-energy proton collisions, similar to the Big Bang.



In theory, matter and antimatter should have annihilated each other in equal measure

But we see more matter than antimatter, which hints at an early imbalance

Are we really alone in the universe, or is life out there?

Where is everybody?

There are trillions of galaxies, but we've never found other signs of life

Our planet is one of hundreds of billions of worlds in our galaxy, itself one of several trillion galaxies in the universe. If life started on our planet, it's fair to think that it started on at least one of these other worlds, too. The only problem is, we've never heard from anyone. This is known as the Fermi Paradox, first postulated by Enrico Fermi in 1950. There's no one single good answer, but we've got a few ideas.

The first, and perhaps most likely, is that we simply haven't looked hard enough yet. We've only found planets around other stars in a tiny

portion of our galaxy, and we can't yet study these for signs of life. It might be that, as our methods improve, we stumble across countless planets teeming with life.

Another possibility is that distances are simply too vast, and time scales too short, for us to make contact. Intelligent life has only existed on our planet for around 100,000 years, a blink of an eye in the universe's 13.8 billion-year-history. Life may spring up on worlds for only a short period of time and rarely overlap. This leads into another idea that intelligent life may ultimately

be eradicated, either via self-induced or natural catastrophes like nuclear war, or asteroid impacts. This is known as a Great Filter, and we're not sure if we've passed one of these tests yet, or if it's yet to come. Life may also be much more unlikely than we thought, and the intelligent life on our planet may be a fluke.

A more recent theory points out that we are relatively early in the universe. The last stars will not die out for trillions of years, so we are much nearer to the Big Bang, and perhaps other life hasn't formed yet in abundance.

2009

YEAR THE KEPLER TELESCOPE WAS LAUNCHED

4.2
light years

CLOSEST
EXOPLANET
TO EARTH,
PROXIMA B

3 27,710
light years

MOST DISTANT EXOPLANET WE'VE FOUND

1992

YEAR FIRST PLANET
WAS CONFIRMED
BEYOND THE
SOLAR SYSTEM

29
Jupiters

MASS OF MOST MASSIVE
EXOPLANET WE'VE SPOTTED

What happens at a black hole?

Strange physics takes place in these massive gravitational anomalies

We have a decent understanding of what happens around a black hole. But when you cross the event horizon beyond which the gravitational pull traps even light, things get a bit more difficult to grasp.

Black holes result from the collapse of giant stars, with supermassive black holes forming at the centre of galaxies when other black holes merge. They are huge wells of gravity, with billions of times the mass of our Sun packed into a tiny space.

Around the event horizon, stars and material can orbit, where they might be torn apart by the intense gravity of the black hole. This material swirls around the event horizon before crossing the boundary, but what happens next isn't clear. At the centre is thought to be a singularity where all the matter gets crushed into a point. Around this, physics is likely to go crazy, with gravity stretching anything inside.

Some theories suggest that black holes do sometimes spit matter back out, in the form of Hawking radiation. However, this is poorly understood at the moment; we just don't really know a lot about what's going on inside these massive objects.

"Black holes result from the collapse of giant stars"

Inside a black hole

The various components of these amazing cosmic phenomena

Event horizon

All black holes have a boundary beyond which nothing can escape their gravitational pull.

Disc

Some black holes have discs of superheated dust and gas swirling around them.

Radiation

It's thought black holes do cause the emission of some information in the form of Hawking radiation.

Singularity

At the centre of a black hole is a singularity where matter is crushed into an infinitely small point.

Some black holes fire out huge jets of particles from their cores

The Event Horizon Telescope

Strange as it might seem, we've never actually seen a black hole. They can be billions of times more massive than our Sun, but only a few times bigger in size, making them difficult to see. But that could all change soon. In April 2017, scientists combined the power of telescopes around the world to turn Earth essentially into one giant telescope, called the Event Horizon Telescope (EHT). They pointed them at the supermassive black hole at the centre of our galaxy, called Sagittarius A*, and gathered as much light as they could.

The amount of data collected was huge – so much that it had to be flown between locations. But the team are hopeful that when the data is fully analysed, which should be within a year, they'll discover that they managed to find the outline – the event horizon – of Sagittarius A*.

Space hunters

The EHT project used various telescopes around the world.

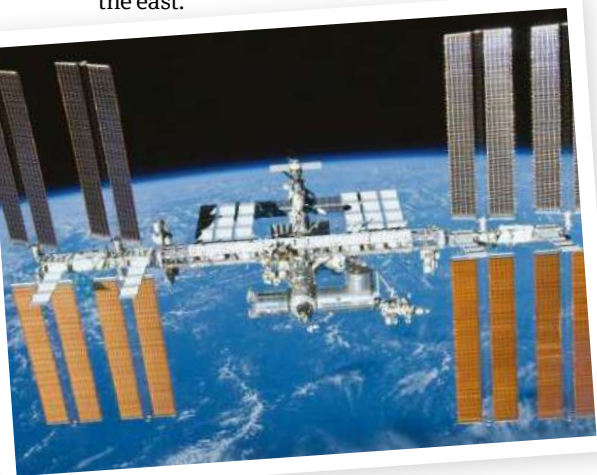
How you can see the ISS

Tracking down the football pitch-sized space station

If you know where to look, it's not too hard to spot the International Space Station (ISS). The station regularly flies over different locations on Earth, and it will look like a bright star rapidly moving across the night sky.

The orbit of the ISS takes it up as far north as the UK and Canada and as far south as Australia and Brazil. Its orbit is tilted at 51 degrees relative to Earth's equator, so each time it makes an orbit it will move over a different area.

To find the ISS, visit spotthestation.nasa.gov to see where it is and get alerts. In the Northern Hemisphere, it will take about five minutes to move across the sky from the western horizon to the east.



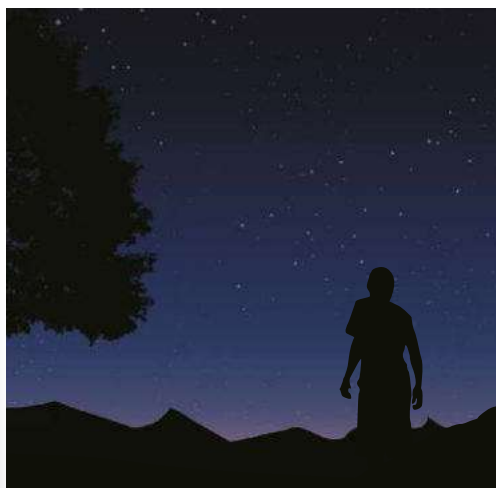
Step by step Your guide to catching a glimpse of the ISS



1 Check online
Use an online tool like spotthestation.nasa.gov to find out if the ISS will be flying over your location. It is most visible just before dawn or soon after dusk.



2 App and weather
Next, you'll need to download an ISS tracker app to check when it'll fly overhead. You'll also want to make sure the weather is clear so that you can see it.



3 Get ready
Wrap up warm, then head outside at least five minutes before the ISS flies over to give your eyes time to adjust to the darkness.



4 See the ISS
Now look towards the western horizon if you're in the Northern Hemisphere. You should see the ISS moving like a rapid star across the night sky to the east.

The Apollo 1 disaster

How three astronauts tragically lost their lives at the dawn of the space age

On 27 January 1967, three astronauts – Gus Grissom, Ed White and Roger Chaffee – entered the Apollo 1 capsule. The crew was taking part in a 'plugs-out' test, where the capsule would run on its own power. It was a simulated launch ahead of the actual event several weeks later, when the capsule would orbit Earth before landing.

During the test, the capsule was filled with pure, high-pressure oxygen to mimic the conditions in orbit. This was designed to drive out nitrogen-containing air. However, it also

produced a highly flammable environment. At 6.30pm, an unidentified electrical arc ignited the gas. Flames immediately engulfed the capsule. Unable to open the hatch quickly enough to escape, the astronauts inside perished.

Significant changes were made to the Apollo capsules after. The hatch was replaced with one that could be opened in seven seconds, while the amount of oxygen in the capsule was reduced. Humans would walk on the Moon during the Apollo 11 mission less than three years later, but at significant human cost.



From left to right: Gus Grissom, Ed White and Roger Chaffee

© NASA/Kipp Teague

Scale of the universe

We investigate the size of the cosmos from the smallest thing we know of to the biggest

As Douglas Adams famously wrote in *The Hitchhiker's Guide To The Galaxy*: "You may think it's a long way down the road to the chemist, but that's just peanuts to space." He wasn't wrong: space is infinitely vast.

At the smallest level we find quarks, the fundamental particles that make up protons and neutrons inside atoms. They are smaller than 86 billion billionths of a centimetre,

2,000-times smaller than a proton, which is itself 60,000-times smaller than a hydrogen atom. A DNA double helix is about 40-times bigger, and a grain of sand is then 1 million-times bigger.

Jumping out to our planet, it measures about 12,750 kilometres across. That's about 109-times smaller than our Sun, 1.4 million kilometres across. Moving out, the diameter of our Solar System is debated, but taking it to be the

outermost planet Neptune, that would make it 9.09 billion kilometres across. That's about 0.001 light years; our galaxy is 100,000 light years!

That's just one part of a massive group of galaxies we're part of called the Virgo Supercluster, which spans 100 million light years. In the grand scheme of our observable universe, 46 billion light years across, it's a blip. Who knows what lies beyond it?

Observable universe ~ 10^{28} metres

The furthest light we can see in the universe makes it 92 billion light years wide.

VISIBLE UNIVERSE

874 000 000 000 000 000 000 000 m

GALAXY CLUSTER

95 000 000 000 000 000 000 000 m

From quarks to the universe

How fundamental particles stack up to the cosmos

Milky Way ~ 10^{21} metres

Our galaxy is about 100,000 light years across.

MILKY WAY

1 045 000 000 000 000 000 000 m

SILICON DIOXIDE MOLECULES

0.000 000 001 m

Atomic nucleus ~ 10^{-12} metres

An atomic nucleus is more than 10 million-times smaller than a grain of sand.

0.000 000 000 000 01 m

OXYGEN NUCLEUS

Human stride ~1 metre

An average human stride is almost one metre in length.

SAND GRAIN

0.0005 m

QUARK

0.000 000 000 000 000 001 m

Quarks ~ 10^{-16} metres

The smallest things we know of, quarks make up protons and neutrons in atoms.

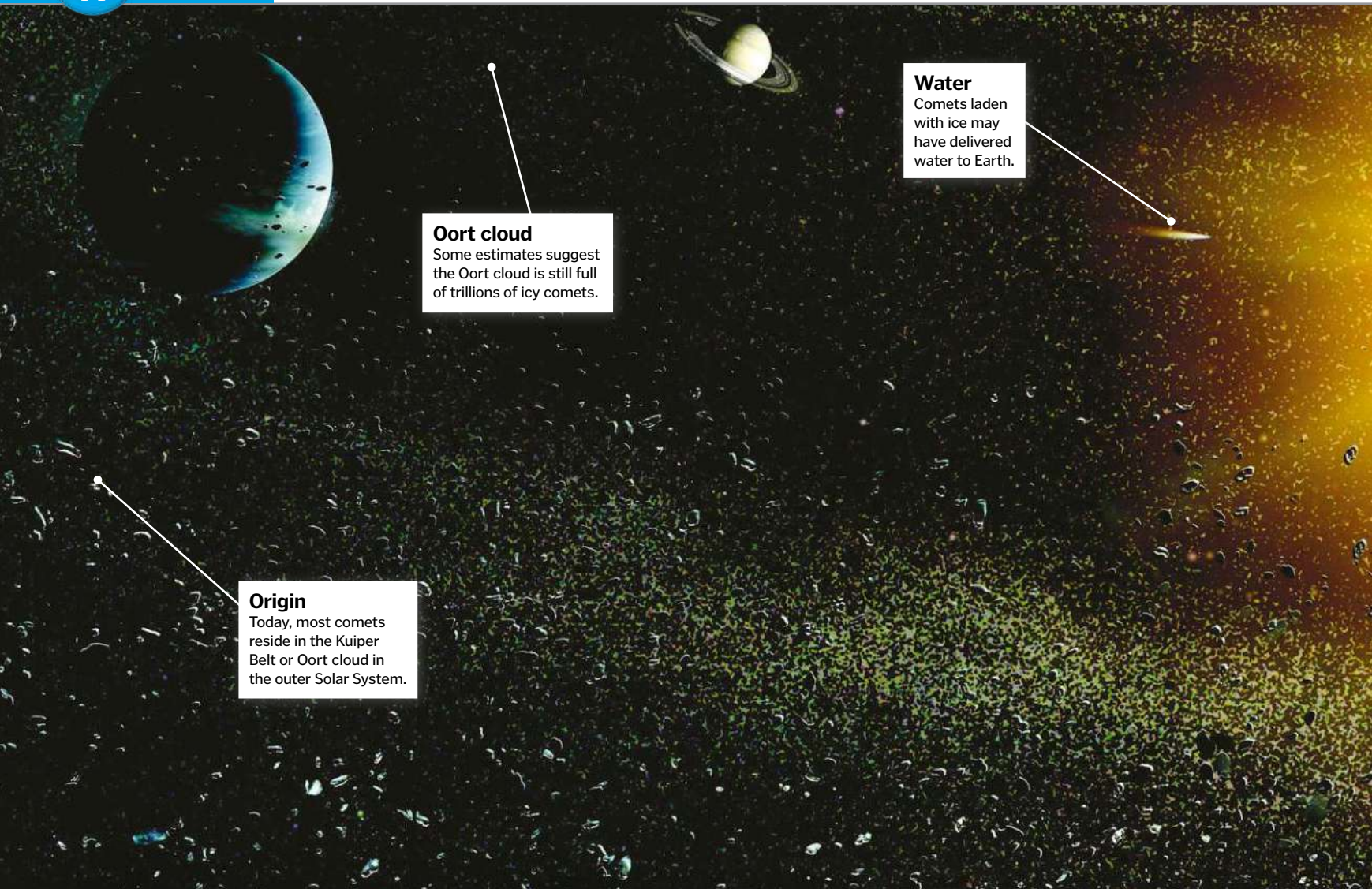
EARTH

12 756 000 m

Earth ~ 12.75×10^6 metres

Our planet is about four-times bigger than the Moon.

SOLAR SYSTEM



Oort cloud

Some estimates suggest the Oort cloud is still full of trillions of icy comets.

Water

Comets laden with ice may have delivered water to Earth.

Origin

Today, most comets reside in the Kuiper Belt or Oort cloud in the outer Solar System.

The Late Heavy Bombardment

How this tumultuous period may have given rise to life on our planet

When Earth first formed more than 4 billion years ago, it began as a molten rocky world devoid of water and, as a consequence, life. But when a flurry of comets came swinging into the Solar System, pounding every world, our planet may have been given the water it so desperately needed.

This period is known as the Late Heavy Bombardment (LHB), occurring about 4.1 to 3.8 billion years ago. During this time, billions of comets from the outer Solar System were sent swinging inwards, crashing into the planets and their moons.

Evidence for the LHB mostly comes from the Apollo missions, which brought back numerous rocks from the Moon. Some of these were impact melt rocks, and they were dated as being 3.8 to 4.1 billion years old, with a particular grouping

of ages around this time hinting at numerous impacts. Various meteorites have also lent evidence to the theory.

We can still see the remnants of this event today elsewhere, with many visible craters persisting from the LHB. On Earth, however, most of our craters from this time are gone, as our geologically active world gradually hid them from view through the shifting of tectonic plates and other processes.

What caused this period is not entirely clear. One of our best theories at the moment concerns the motions of Jupiter and Saturn. When these giant planets first formed in our Solar System they were much closer towards the Sun than they are now, gradually moving out and entering into an orbital resonance, or pattern, with each other.

This had the knock-on effect of causing huge gravitational disturbances in the Solar System. One consequence of this was that Neptune was pushed out into a region of icy debris left over from our Solar System's birth. This caused billions of comets and asteroids to be flung inwards, resulting in a 'shooting gallery' as the worlds were pummelled. Eventually, the orbits of the planets stabilised, and our Solar System became the relatively peaceful place that our planet exists in today.

This is not the only theory for the LHB, however. Some suggest that a delayed formation of Uranus or Neptune may have been the cause, while others contend it never happened at all. Evidence seems to favour a Jupiter-caused LHB at the moment, but our beginnings are still not quite clear.

"Evidence for the LHB mostly comes from the Apollo missions"

Craters

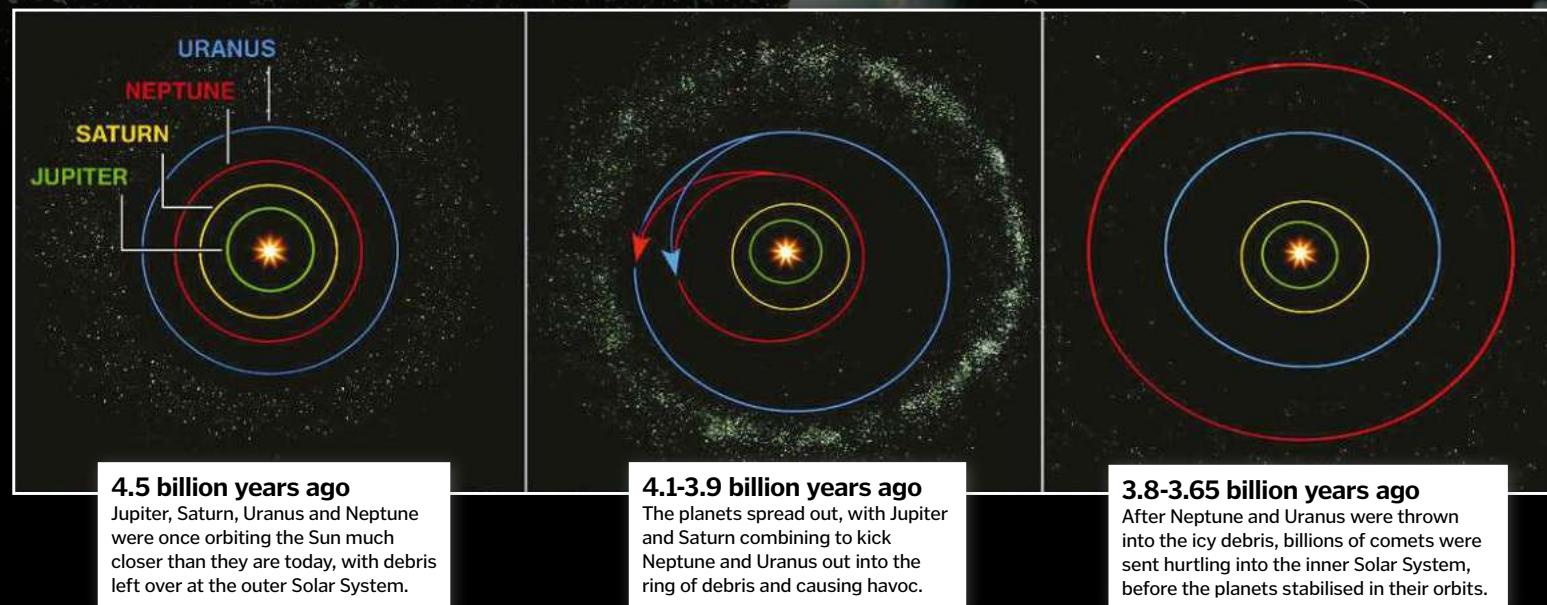
The LHB left many visible scars on the moons and planets.

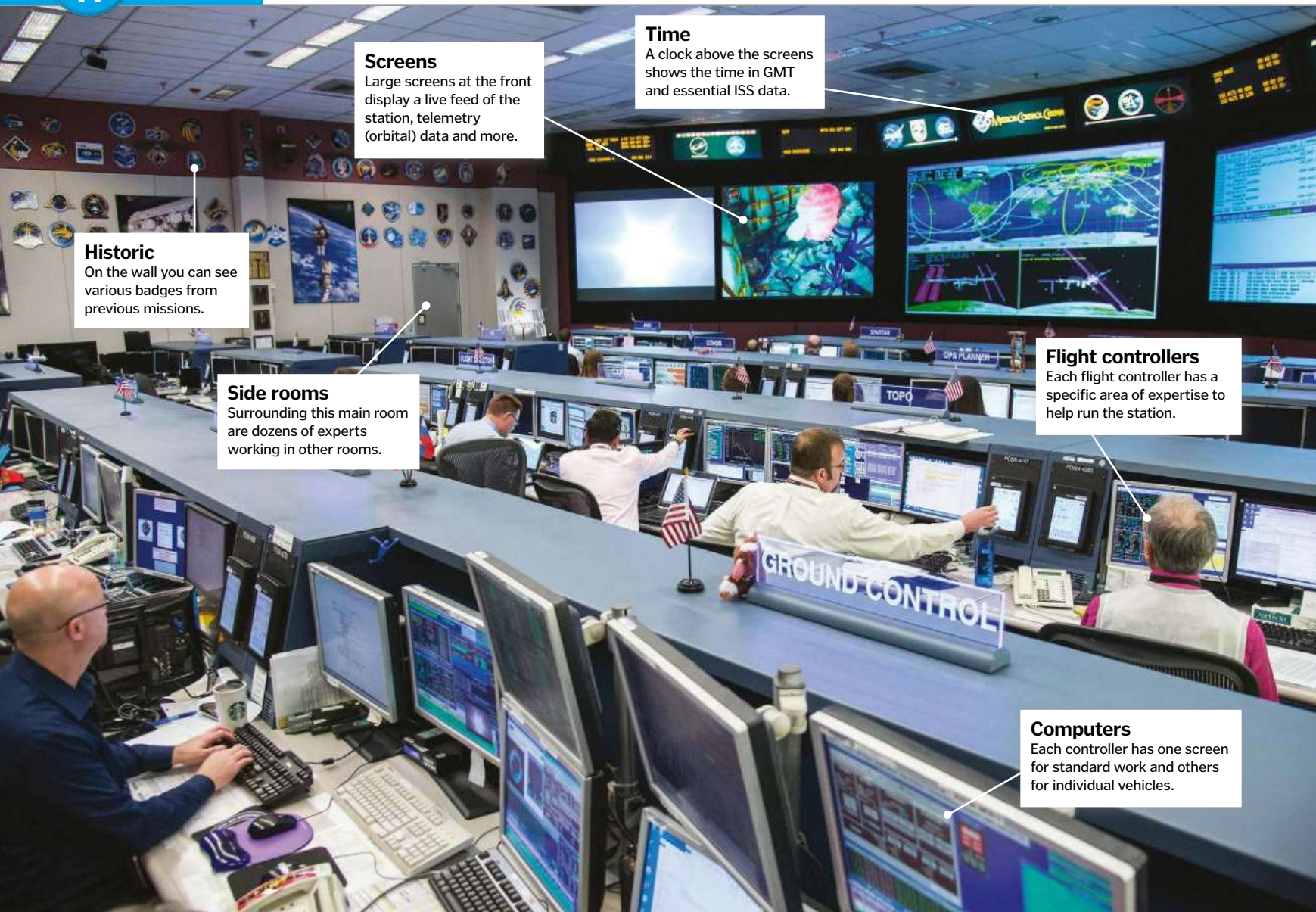
Impacts

Earth may have been impacted during the LHB every 15,000 years.

The Nice model

According to this theory, Jupiter and Saturn may have caused the LHB period





Screens

Large screens at the front display a live feed of the station, telemetry (orbital) data and more.

Time

A clock above the screens shows the time in GMT and essential ISS data.

Historic

On the wall you can see various badges from previous missions.

Side rooms

Surrounding this main room are dozens of experts working in other rooms.

Flight controllers

Each flight controller has a specific area of expertise to help run the station.

Computers

Each controller has one screen for standard work and others for individual vehicles.

Inside mission control

How NASA keeps the International Space Station running

There are many mission control centres (MCCs) around the world, but perhaps none are as famous as NASA's Christopher C Kraft Jr Mission Control Center in Houston, Texas. This historic building was once used to operate the Apollo missions and Space Shuttle. Today, it is responsible for the International Space Station (ISS).

The most recognisable part of the MCC is the 'front room', a room full of computers and big screens. To talk to Earth, get assignments or fix problems, American astronauts on the ISS will liaise with the front room, specifically the CAPCOM (capsule communicator). About a dozen other flight controllers are responsible for operating the ISS. The teams work in shifts around the clock, 365 days a year, and also communicate with other control centres.

Each flight controller reports to the flight director, who is ultimately in charge of the MCC.

They have the final call on any decisions like manoeuvring the ISS or docking a spacecraft. Flight controllers train from one to three years to be allowed in this room, while flight directors have much more experience. Working here is both prestigious and extremely important.



A different control room was used for the Apollo missions (Apollo 11 shown) than for the ISS

Five other control centres

**NASA
Goddard
Space Flight
Center
Greenbelt,
Maryland**
Monitors: Hubble
Space Telescope

**European Space
Operations Centre
Darmstadt, Germany**
Monitors: ESA satellites and probes

**RKA Mission
Control Center
Korolyov, Russia**
Monitors: The ISS

**NASA Jet
Propulsion
Laboratory
California**
Monitors: Unmanned
interplanetary missions

**Beijing
Aerospace
Command and
Control Center
Beijing, China**
Monitors: Chinese
space programme



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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears



Laura studied biomedical science at King's College London and has a master's from Cambridge. She

escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung



Having earned degrees from the University of Nottingham and Imperial College London, Alex has

worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean



Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first

book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Sarah Banks



Sarah has a degree in English language and literature and has been a writer and editor for more than a decade.

Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Joanna Stass



Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts.

She is particularly interested in natural world wonders, innovations in technology and adorable animals.



Chimpanzees frequently use tools, while bonobos have only rarely used tools in captivity

What are the differences between chimpanzees and bonobos?

Terry Hamilton

Chimpanzees and bonobos are the closest living relatives to humans, sharing close to 99 per cent of our genome, and closer to 100 per cent of each other's. However, although they look very similar, there are many key differences. Firstly, bonobos live exclusively in the Democratic Republic of Congo, while chimps can be found across western and central Africa. Bonobos are also smaller and slimmer compared to chimps, have pink lips as opposed to brown, and shorter head

hair. A chimp's facial colouring will also change with age, whereas a bonobo's will remain black. Their social behaviour also differs greatly, as groups of chimps are led by an alpha male who will use aggression to maintain order, while nonviolent bonobos are dominated by females who use sex to keep the peace. Bonobos also have a higher-pitched voice compared to chimps, who prefer to communicate with deeper hoots, screams and grunts. JS

What is the difference between table salt and sea salt?

Kiera Timpson

Table salt and sea salt have the same chemical composition, but different processing methods give them a slightly different taste and texture. Sea salt is produced by evaporating the water from seawater or saltwater lakes, leaving behind salt but also small amounts of minerals such as magnesium, calcium and potassium, which can affect flavour. The large salt crystals give it a relatively coarse texture. Table salt, on the other hand, is typically mined from salt deposits. It is washed, purified and stripped of any contaminants. Additives are then added to prevent it from clumping. Iodised salt also contains extra potassium iodide. AC

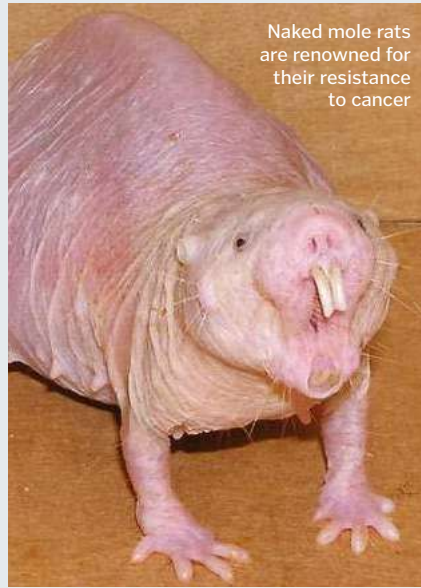


Table salt and sea salt are both crystals of sodium chloride

Is it true that mole rats don't get cancer?

Piers Liebhart

■ Sadly not. For a long time, people thought that naked mole rats didn't get cancer, but last year two cases were reported for the first time. However, the species do seem to be more resistant to the disease than other animals. Cancer is caused by faults in the DNA that change the way that cells behave. They stop doing their normal job and start to divide uncontrollably, most often clumping together to form a tumour. If parts of the tumour break away, they can travel around the body and spread the disease to other organs. The resistance in naked mole rats seems to be partly to do with a sugar called hyaluronan – they pump a heavy version of the molecule into the spaces between their cells. It's thought that the trait evolved to keep their skin flexible, but it also seems to stop their cells sticking together to form tumours. **LM**



Naked mole rats are renowned for their resistance to cancer

Experts recommend indoor humidity levels of 40-50 per cent for optimum comfort



How do room humidifiers work?

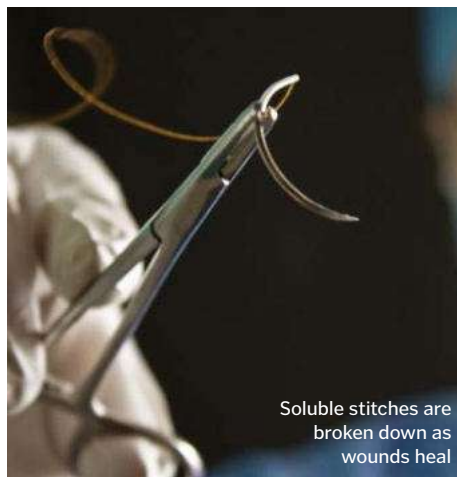
Rachel Ansem

■ Humidifiers use a range of mechanisms to force extra moisture into the air, increasing its humidity. An evaporative humidifier employs a fan to run air through a damp filter soaked in a reservoir of water. As the dry air passes through, some of the water evaporates, adding moisture to the air. A steam humidifier, meanwhile, boils water, releasing hot steam. Finally, inside an ultrasonic humidifier, a diaphragm vibrating at ultrasonic frequencies converts liquid water into tiny droplets, producing a cool mist. Using a humidifier can reduce the symptoms of respiratory conditions or dry skin. **AC**

How do dissolvable surgical stitches work?

Francesca Basso

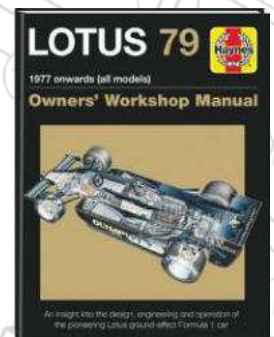
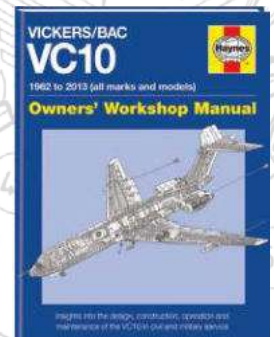
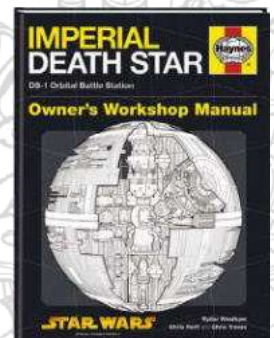
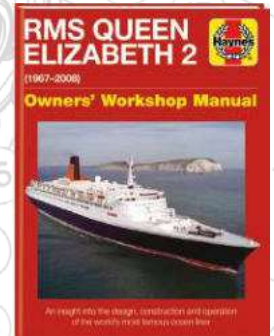
■ Dissolvable sutures were originally made from the intestines of animals – most often sheep, goats or cows. The thread was made from tough, natural material known as connective tissue, which contains strong fibres of the protein collagen. The tissue is broken down into ribbons, which are spun together to make thread. Collagen can be broken down by enzymes made naturally in the body, allowing the stitches to dissolve slowly as the wound heals. This process can be delayed by coating the thread in chromium salt, holding off the action of the enzymes a little longer. Alternatives include synthetic threads made from polyglycolide acids or polydioxanone. **LM**



Soluble stitches are broken down as wounds heal



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'Neon' highlighter pens owe their luminous glow to fluorescent chemicals



What makes highlighters neon?

Ben Reed

■ Highlighter ink contains fluorescent compounds that absorb ultraviolet (UV) light and emit this energy as visible light, creating extra luminous 'neon' colours (although these colours have nothing to do with neon gases). When UV light hits dyes within fluorescent ink, its electrons absorb high-energy UV wavelengths of light, entering an 'excited' state. As the electrons drop back to their original state, this excess energy is

emitted as visible light. While a normal yellow ink absorbs and re-emits wavelengths within the visible light spectrum, a fluorescent ink absorbs portions of both visible and UV light, effectively converting the UV light into visible light and emitting up to twice as much visible light as a standard ink. This effect is even more obvious if you shine a UV light onto highlighter ink in a darkened room – the UV light is converted into visible light, making the ink glow. **AC**

How does Blu-tack work?

Daniel Mestriner

■ Weak electrostatic forces between the synthetic polymers that make up Blu-tack and the surface it is applied to give Blu-tack its stickiness. Polymers are long chains of molecules, which are also responsible for Blu-tack's elastic properties. It contains mineral oils that prevent it from sticking too strongly, allowing it to be repositioned. Blu-tack is also easily deformable, meaning that it moulds to the shape of the surfaces it is pressed between, squeezing into any gaps and maximising the contact area. This effect becomes stronger over time as Blu-tack seeps further into any pores in the surfaces it is stuck to. **AC**

The exact workings of Blu-tack have never been revealed by its manufacturer



Clap on lights require a special sort of sound-activated switch



How do 'clap on' lights work?

Denise Allen

■ Clap on lights normally use a special sort of sound-activated switch, like a 'clapper,' which fits between a mains socket and a plug-in electric lamp. When you clap your hands, the sound is detected by a microphone, converted into an electric signal, and sent to an electronic circuit. This triggers a switch to turn the light on or off, but only if the signal has a frequency and intensity within the range of someone clapping. The circuit filters out other sounds, so the lights shouldn't switch for sound that isn't a clap. **TL**

FASCINATING FACTS

Why are electric cars so expensive?

Electric cars' price tags are partly driven by the high cost of their batteries. As battery technology improves and electric cars become widespread, experts predict that their cost will fall substantially. **AC**



Electric cars are predicted to become cheaper than conventional cars within the next decade

Why does garlic make your breath smell?

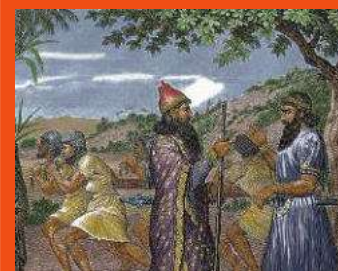
The familiar smell of garlic breath is down to chemicals containing sulphur and selenium. It's thought that these come from the lungs, rather than chemicals retained in the mouth. **LM**



The breakdown of garlic creates smelly gases that enter the lungs

What was the world's first empire?

The world's first empire is believed to be the Akkadian Empire, which was a Semitic-speaking empire of Mesopotamia that ruled from around 2300 BC to 2200 BC. **SB**

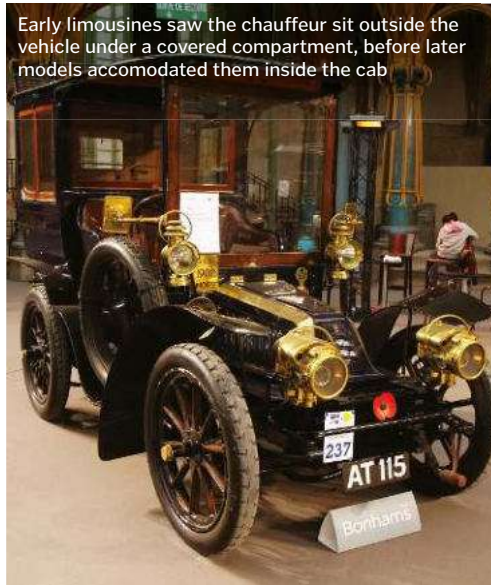


The Akkadian Empire was centred in the city of Akkad, which is believed to have been in what is now Iraq

Who invented the automobile limousine?

Lance Johnson

■ The first automobile limousine was built in 1902, but it is not known who invented it. The driver sat outside the vehicle in a compartment that was separate from the passengers, which is how it got its name, because the compartment resembled the cloak hood of shepherds from Limoges in the Limousin region of France. The first stretch limousine was created in Arkansas, US in 1928 by a company called Armbruster. These types of limousine were commonly known as 'big band buses' because they were used to transport bands and their musical instruments around the country. **SB**



How many satellites are in orbit around Earth at the moment?

Vanessa Rose

■ As of 2016, there were around 4,256 satellites in orbit around Earth, of which 1,419 were operational. However, there are thousands more pieces of debris that have broken off from past satellites in space, too. **JS**



Why do British judges wear wigs?

Alison Perry

■ Wigs became part of the legal dress code in English courts for judges and barristers simply because Charles II had made wigs essential wear for polite society in the 17th century. As such, wearing a wig was more common than not wearing one. While it took a while for the trend to catch on in the courtroom, wigs are still worn today, although not as much. **SB**



How do motion detector switches work?

Petra Kovalev

■ This depends on the type of sensor. The most common type is passive infrared, which detects heat signatures. If the signal changes quickly – because a warm body is moving within its field of view – it trips the switch. Alternatives include vibration detectors, which use a weight on a lever to detect motion transmitted through the floor, and microwave or ultrasonic detectors, which send out pulses and measure the reflections that bounce back. These work in a similar way to the echolocation used by bats, detecting changes in the time it takes for a signal to return. **LM**

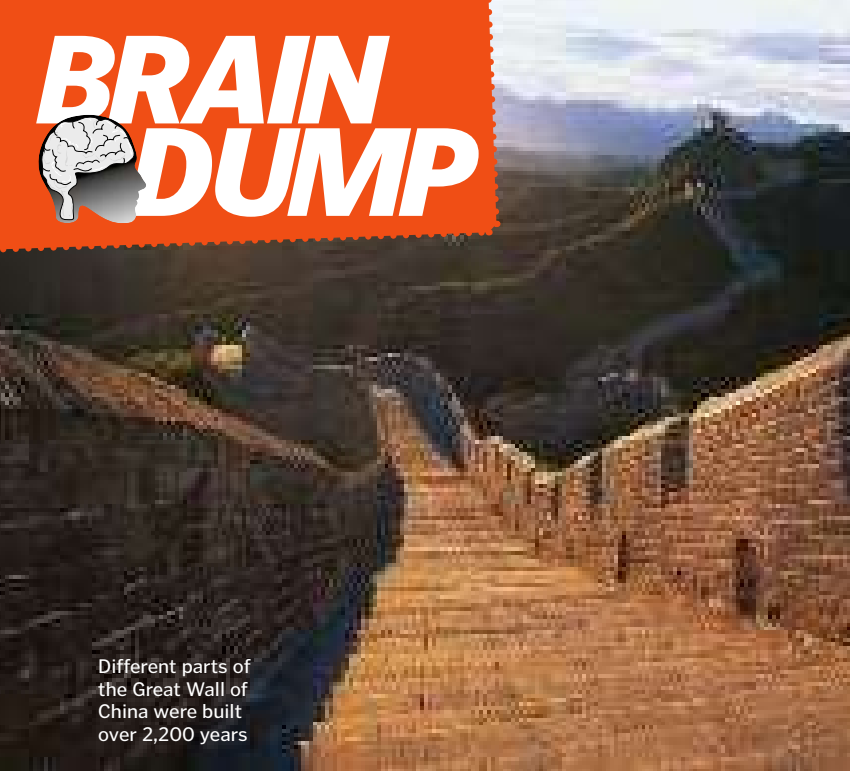
Do rocket launches create a lot of pollution?

Felix Davis

■ Rockets move by combining fuel with an oxidiser and shooting the resulting gasses out through a nozzle. Some use liquid hydrogen and oxygen, releasing mainly water, but others create hydrochloric acid, particles of alumina, nitrogen oxides (which form nitric acid in the atmosphere), carbon dioxide, or black carbon (soot). The amount of carbon dioxide is minimal compared to the volumes we create on the ground, but the hydrochloric acid and nitric oxide can affect the ozone layer, effectively punching a hole where the rocket passes through. Luckily, this closes up within weeks. Soot is the biggest pollutant, reaching high up into the atmosphere and staying there for years. **LM**

Launches create different pollutants depending on the rocket fuel





Different parts of the Great Wall of China were built over 2,200 years

How long did it take to build the Great Wall of China?

Jean Dubois

There were actually several great walls built in China at different times, the earliest probably around 250 BC. Over the following centuries different dynasties extended the walls, connected some of them up and built new sections, a process that lasted almost an incredible 1,900 years. The section best known today as the Great Wall of China was the last part to be built, finished around 1644 CE after almost 300 years of construction. **TL**

70,000 cochineal bugs are crushed to produce 450 grams of red dye



What are food colourings made of?

Izzy Polden

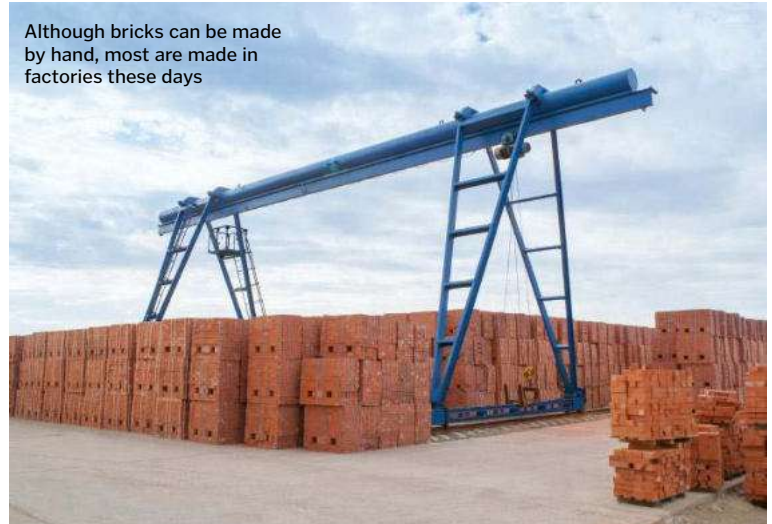
Food colouring can be produced from either natural or artificial sources. Natural food dyes are usually pigments extracted from plants. The carotenoids that give pumpkins their bright orange colour, chlorophyll, which is found in all green leaves, and turmeric, which is a deep yellow substance obtained from the underground stem of an Indian plant, are all examples. However, some come from insects instead, such as carminic acid, a red dye used in many foods and cosmetic products, which is extracted from a bug called the cochineal. Artificial food colourings are produced from coal or petroleum byproducts, and are much cheaper, longer-lasting and can create a wider range of hues. **JS**

How are bricks made?

Thomas Pullman

Bricks are made from clay. First, diggers extract the clay from quarries. It is then transported to a brick factory, where a machine crushes it to get rid of the lumps. Water is then added to the smooth clay to make it soft and sticky, ready to mould into a brick shape. A machine squeezes the clay into rectangular moulds, and sand is used to pop the bricks out of the mould. To harden the bricks, they're placed in a drier for 24 hours. Once dry, the bricks go to the kiln to be fired. The bricks are then ready to be laid. **SB**

Although bricks can be made by hand, most are made in factories these days



What is Muzak?

Ella Tandoh

Muzak is actually a brand name but is now commonly used to describe any easy-listening background music played in restaurants, shops and elevators. The Muzak company was founded by Major General George Owen Squier in 1934, and became the best-known supplier of background music in the United States until it was bought by Mood Music in 2011. After perfecting a method for transmitting music across electrical wires in the 1920s, Squier had originally planned to offer the service to homes, but when this market was eclipsed by radio, he targeted businesses instead, claiming the music would help to boost staff productivity. **JS**



The Muzak company brought in top bands and orchestras to create an archive of original music

FASCINATING FACTS

Can emergency vehicles trigger traffic lights to change?

Nikolai Lukyanenko

In the US, traffic lights are fitted with a receiver that changes the lights when triggered by a transmitter on an approaching emergency vehicle, but the technology is far from universal. **TL**



Traffic signals can sometimes be triggered by approaching police cars



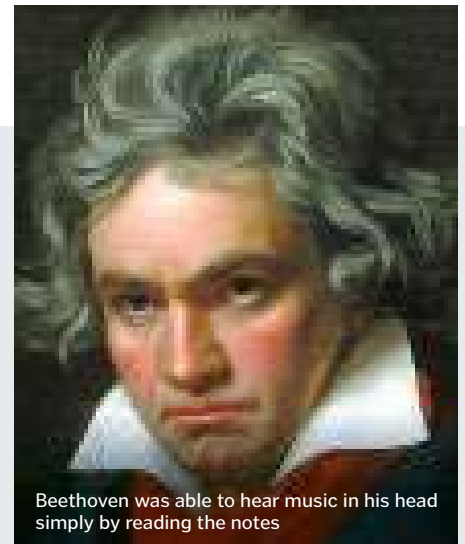
Strobe lights are a popular visual effect in nightclubs

Why do strobe lights make the world look like it's in slow motion?

Greg Ford

Because strobe lights quickly flash on and off, they show us the world as a series of short snapshots. We don't get to see what happens in between the flashes. The slow motion 'stroboscopic effect' happens when we look at something with continuous motion, like a wheel

spinning. If the strobe flashes slower than the spin rate, then the wheel spins all the way around and a little bit further between each snapshot we see, making the wheel appear to move slower than it really is, because in the snapshots it only appears to have moved slightly, not all the way around. **TL**



Beethoven was able to hear music in his head simply by reading the notes

How did Beethoven compose music if he was deaf?

David Elias

Ludwig van Beethoven was not born deaf. When he began to lose his hearing in his mid 20s, he had already achieved great musical successes. It wasn't until Beethoven reached his mid 40s that he became almost completely deaf. Having played music for several decades, Beethoven was able to 'hear' notes just by looking at them on a page. He knew how instruments worked – independently and with other instruments and sounds – and, as his hearing slowly deteriorated, his imagination was able to fill in the gaps when he struggled to hear certain notes and sounds. He was therefore able to compose music without physically hearing it. **SB**

Is there a limit to how tall a skyscraper can be built?

Jenson Simmons

The tallest skyscrapers are currently about 800 metres tall. Taller buildings are possible but difficult. More height means a wider base to support the weight of more floors and the extra structural supports to protect the skyscraper from toppling in the wind. It's also hard to move people over so many floors; there's a current limit to elevator cable length yet to be solved. Over 600 metres and the cable becomes too heavy. Despite these obstacles, experts reckon that using current engineering concepts they could build a skyscraper a mile (1,609 metres) high. But it would be very expensive and the real limit is cost rather than engineering. **TL**

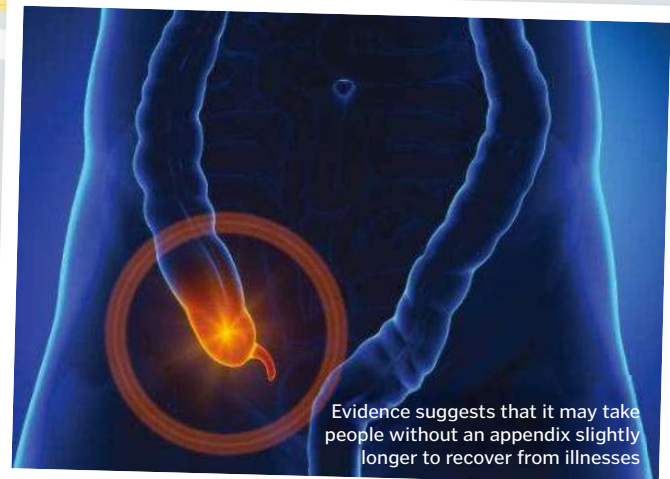
The 830-metre high Burj Khalifa in Dubai is currently the world's tallest skyscraper



What does your appendix do?

Hayley Winner

The true function of the appendix – the small pouch attached to the large intestine – is a subject of much debate in the medical community. Some believe it to be a vestigial organ, once used to help us digest tough leaves and bark but now devoid of a purpose thanks to our evolving diets. This theory is aided by the fact that humans can live comfortably without an appendix after it has been removed. However, others claim that the organ has an important immune function, serving as a reservoir for healthy gut bacteria that aid recovery from infections. **JS**



Evidence suggests that it may take people without an appendix slightly longer to recover from illnesses

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BOOK REVIEWS

The latest releases for curious minds

Science Year By Year

A visual history, from stone tools to space travel

- Author: Clive Gifford, Susan Kennedy and Philip Parker
- Publisher: DK
- Price: £16.99 / \$24.99
- Release date: Out now

Often, historical science books like this one will focus on a few discoveries, sometimes just in a limited period, or perhaps within a specific field. While these books are fantastic for those wanting to learn about set points or single disciplines, it's only with a book like *Science Year By Year* that you are able to get a more rounded idea about how science has progressed.

This book has a single timeline running all the way through it, splitting the centre of the page with years marked using arrows so that you know where – or rather when – you are. From this line, all kinds of scientific discoveries are pulled. There is no separation into physics, mathematics, biology, chemistry, or any other disciplines. Instead, important facts are simply explained in the order they were discovered. It works brilliantly, partly thanks to the simple but fact-packed descriptions of each important date.

There are some awesome facts in there, too. For example, the first known use of the symbol for zero was discovered in India in 876 CE. Before that, while mathematicians had used the concept in calculations, it was never written down. Only after this could a proper decimal system be put in place. Move to the other end of the book (and skip several centuries) and you'll find information about artificial skin, developed in 1981 to help burn victims regrow skin cells.

While popular science is covered – the development of the mobile phone, and the first balloon flight – it's these less common facts that make the book really stand out. Each page is packed with information, with some sections simply explaining an idea with a block of text, and others going into much more detail with dedicated boxes on the subject. A mixture of

real-world photographs and hand-drawn illustrations support the facts, and the combination is excellent. Complex machines are broken down using a cross-section diagram, which is then annotated with information that helps to explain what you are looking at, with

important facts or quotes highlighted. What this means is that you can turn to any page in the book and soak up a huge amount of information. To us, that makes this book a resounding success and one we can't recommend enough.

★★★★★

YOU MAY ALSO LIKE...

History Year By Year

Author: N/A
Publisher: DK
Price: £16.99 / \$24.99
Release date: Out now

If you enjoyed the visual history of science, you will no doubt enjoy this partner title from DK. This book takes the reader on an adventure through time, charting human history from the Stone Age to the modern day.

The Invention Of Science

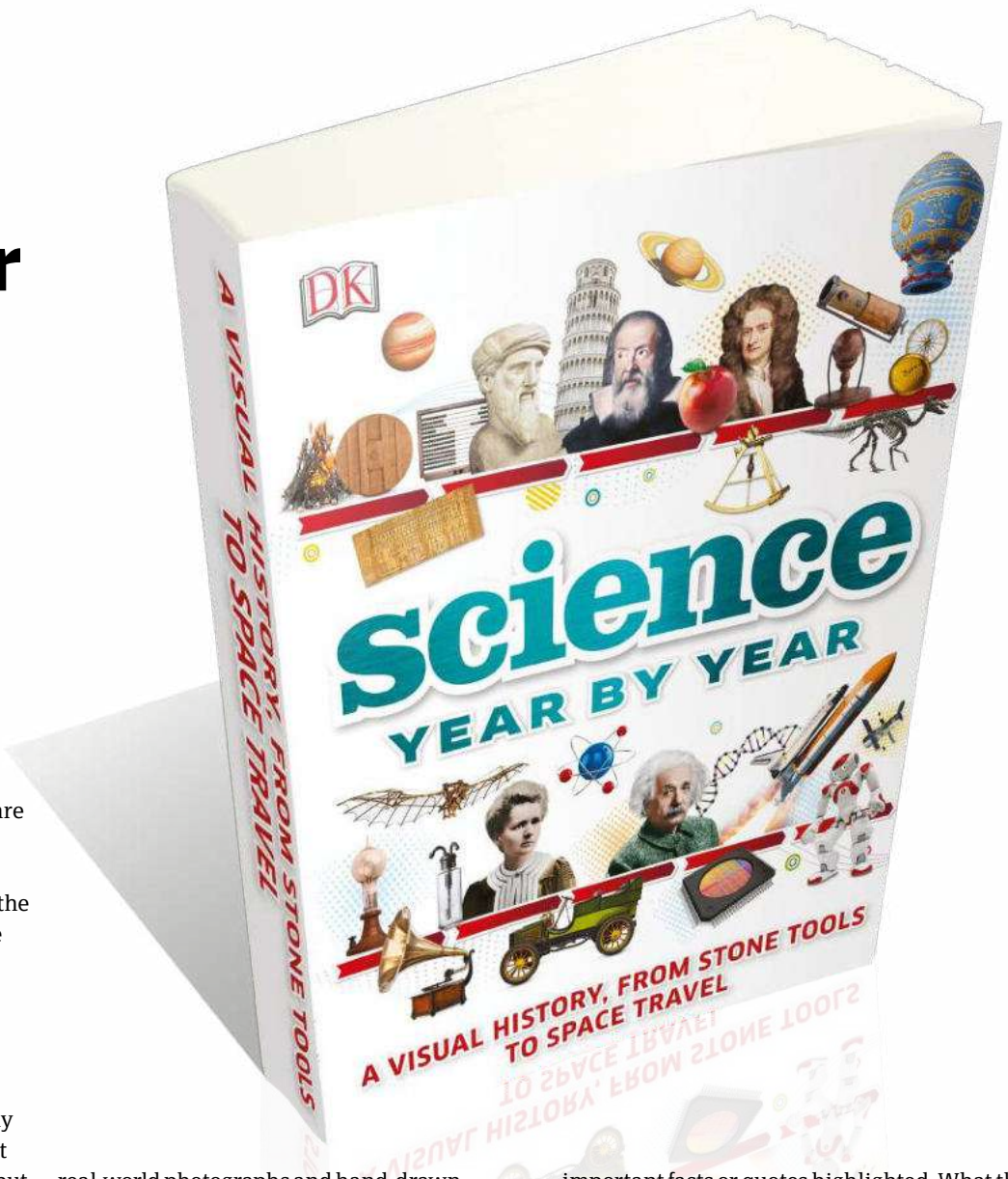
Author: David Wootton
Publisher: Penguin
Price: £12.99 / \$18.99
Release date: Out now

Older readers may be curious to learn more about the scientific revolution. Wootton's fascinating book charts humanity's pursuit of knowledge, and how the scientific method developed.

The Science Book

Author: N/A
Publisher: DK
Price: £16.99 / \$25
Release date: Out now

This book splits science up into different topics, and even gives short biographies on some of science's most important minds. There's a lot to read here, with lovely diagrams showing how famous experiments worked.





Asteroid Hunters

From the dinosaurs to the future

- Author: **Carrie Nugent**
- Publisher: **Simon & Schuster**
- Price: **£8.99 / \$16.99**
- Release date: **Out now**

Certain words indicate a high level of quality, and that's definitely the case with TED, who lend their name here to *Asteroid Hunters*, penned by asteroid hunter Dr Carrie Nugent.

Explaining everything in a concise yet scientific and informative manner, Nugent's book is a wellspring of resources for anyone wanting to know more about these potentially Earth-altering space rocks. With subject matter encompassing some of our planet's own dalliances with destruction and our current attempts at preventing any more threats, this book makes the case for space not being a vast wilderness, but a lawless frontier. It's an approach that really works.

★★★★★

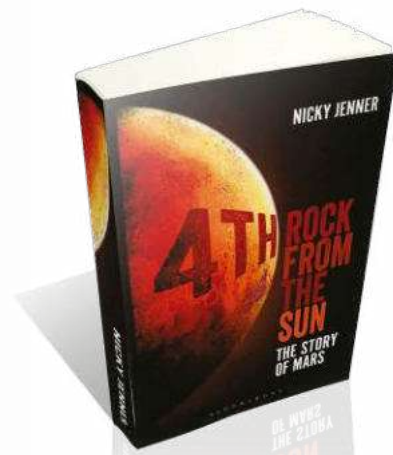
The Gadget Inventor Handbook

A small book for big imaginations

- Author: **Mike Warren**
- Publisher: **QED**
- Price: **£9.99 / \$12.95**
- Release date: **Out now**

Ever wanted to create an LED bracelet? Or a mini vibrating robot? How about a potato clock? Even if your answer to all of these questions is "No", chances are you might well find something else within these pages to inspire you.

Aimed primarily at the younger budding scientists out there, this book contains various step-by-step guides to



4th Rock From The Sun: The Story Of Mars

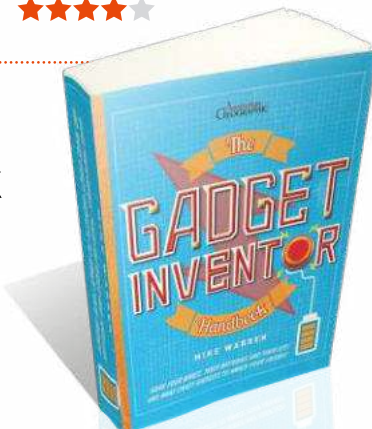
How the Red Planet has inspired humanity

- Author: **Nicky Jenner**
- Publisher: **Bloomsbury Sigma**
- Price: **£16.99 / \$27**
- Release date: **Out now**

For such a barren, lifeless location, Mars has had a lot of mythology ascribed to it. From ancient gods to various references in pop culture, the Red Planet has repeatedly captured the imagination. And imagination is the aim here, with Nicky Jenner attempting a complete chronicle of its influence on Earth.

As our nearest neighbour, it's also arguably our best shot at colonising another planet, and while this isn't the main focus, it isn't ignored. It falls down slightly in its 'is colonising Mars worth it?' conclusion – which seems self-defeating considering the subject – but the journey it takes is worth your time.

★★★★★



creating an array of inventions to make your friends jealous. Along with useful equipment lists and fun facts, everything you need is here to get a project started. This is exactly the sort of book we wish we'd had growing up. If your child is an Einstein-in-waiting, then without doubt this is the book for them.

★★★★★

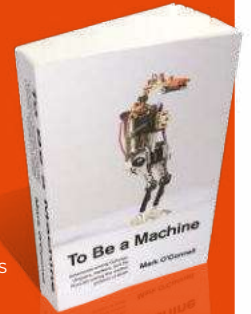
To Be A Machine

Could we direct our own evolution by merging with technology?

- Author: **Mark O'Connell**
- Publisher: **Granta**
- Price: **£12.99 / \$26.95**
- Release date: **Out now**

This book is journalist Mark O'Connell's journey to discover transhumanism, a movement based around the idea that the human body can be released from the limits of biology with the use of technology. O'Connell visits laboratories and conferences to investigate the beliefs of transhumanists, many of whom harbour very eccentric views. As an outsider, O'Connell's wry reactions to some of the more unbelievable expectations add humour. This is a captivating work of investigative journalism, Louis Theroux-like in its delivery and very thought provoking.

★★★★★



The 50 Greatest Wonders Of The World

The best sights on Earth, all in one book!

- Author: **Aaron Millar**
- Publisher: **Icon**
- Price: **£8.99 / \$14.95**
- Release date: **Out now**

Part of Icon Books 50 Greatest series, travel writer Aaron Millar's fantastic book explores Earth's most amazing attractions. The content is split up into each region of the world, and makes the perfect guidebook, with top tips on how and when to see each entry. Including both human made and natural wonders, staples like the Grand Canyon and Mount Everest are present, but Millar also introduces less well-known sights like the Son Doong Cave. There's a lack of colour images but Millar's engaging writing is all the illustration you need. It makes you want to grab your passport!

★★★★★



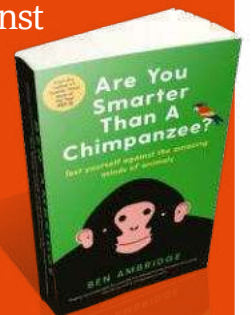
Are You Smarter Than A Chimpanzee?

Challenge your brain against the minds of animals

- Author: **Ben Ambridge**
- Publisher: **Profile**
- Price: **£12.99 (approx \$17)**
- Release date: **Out now**

Both insightful and humorous, *Are You Smarter Than A Chimpanzee?* is one of the most interesting books we've read all year. Page after page of interactive tests and puzzles, Ben Ambridge's great book allows readers to test their brain against the mind power of animals. This is not just a quiz book, though, and raises a number of serious points, explaining the science involved and what the test results reveal. Intelligently and humorously written, this is a fun read that emphasises just how closely connected we are to our primate cousins and other clever creatures.

★★★★★





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Build a water filter

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1 Create the body

First, cut right around the outside of a large plastic bottle, so that you have two separate pieces – the top and the bottom. Take a big piece of cotton wool and press it into the hole at the lid of the bottle to plug the opening. The fine fibres of the cotton wool will catch tiny particles of dirt floating in your water. Place the top of the bottle upside down into the bottom of the bottle.



2 Start filling

The aim here is to remove as much dirt and debris from your dirty water as possible. Start by putting a one-centimetre layer of charcoal in the bottom of the bottle to cover the cotton wool, then pouring in some sand on top of that to cover it. The layer should be around two centimetres thick. Then, take some small pieces of gravel and pour them on top of the sand to create another layer.



3 Layer on layer

Next, add some larger gravel to your filter. Try to keep the layers even and make sure the previous layer is completely covered by the next one. Finally, top the filter off with some larger stones, making sure that the gravel is totally covered underneath. You should now be able to see that the gaps between particles in each layer decrease from top to bottom.



4 Make your mixture

To test your filter, you will need some dirty water. Take a jug of water, pour in some soil and mix it around with a spoon. You'll notice that some of the soil will dissolve in the water, while other bits will remain floating. Next, throw in some grass and leaves. These are the kinds of things that you might find in river water so they will make your experiment more authentic.



5 Pour it in

Now you can pour your dirty water into the filter. The water contains particles of lots of different sizes, and these will be stopped at different points in the filtration process. The stones should stop the leaves and grass, while some soil will make it down further to the gravel or sand. The water left at the end will look much cleaner, but it's still not safe to drink!

DISCLAIMER
DO NOT DRINK THE WATER YOU FILTER IN THIS EXPERIMENT! WHILE THE FILTER TRAPS DIRT, IT COULD STILL BE CONTAMINATED BY BACTERIA!

"Different-sized particles will be stopped at different points in the filtration process"

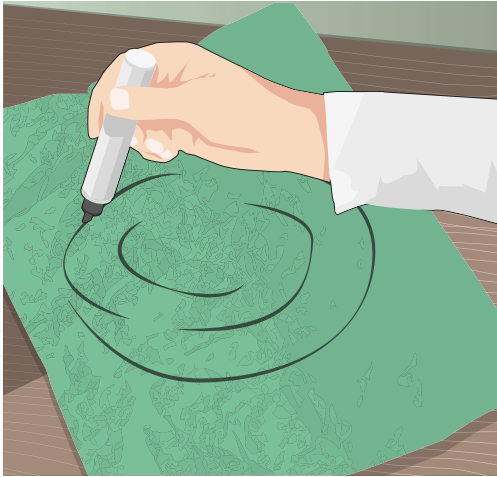
In summary...

The gaps within the filter get smaller as the water trickles through it, and fewer particles can get through these gaps. By the time it reaches the bottom, the filter has stopped almost all the dirt particles, leaving much cleaner water filtering out the bottom of the bottle.

Disclaimer: Neither Future Publishing nor its employees can accept liability for any adverse effects experienced after carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

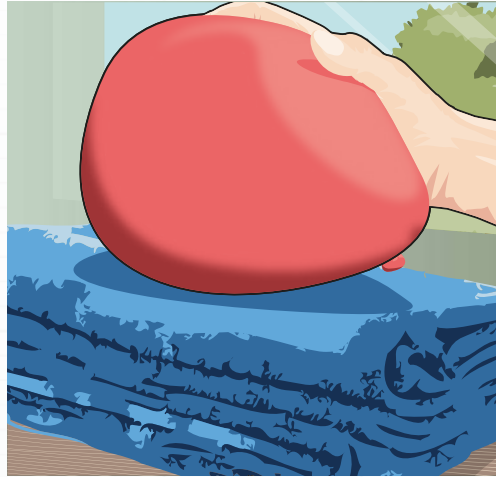
Make a dancing snake

How does static electricity make objects stick together?



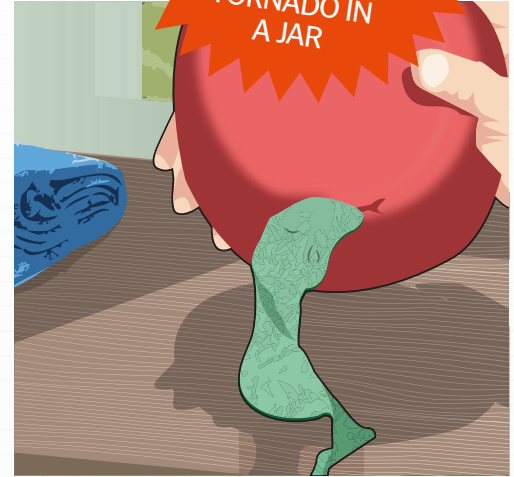
1 Create your snake

To make your snake, take a large bowl and draw around it on a piece of tissue paper. For the best results, use the thinnest tissue paper available, picking whichever colour you want your snake to be. Now draw a spiral inside the circle you've made, just like a coiled snake; this will form the body. Try to keep the body width the same all the way around, and make the snake's head the centre of the coil.



2 Cut and charge

To finish off your snake, cut it out along the lines you've just drawn. You can also draw some eyes and nostrils on the snake, and even attach a tongue made of red tissue paper to it to make it look even more realistic. Now your snake is ready, put it to one side and find a balloon. Blow it up and tie a knot in it. Now you need to charge it with static electricity by rubbing it on something woollen – like a blanket – for around a minute.



3 Make it dance

Static electricity will cause objects to attract to each other. In this case, the charge on the balloon, which you created when you rubbed it on the wool, will cause the snake to stick to the balloon. Hold the charged balloon above the snake, and then slowly start to move it downwards. When the balloon is around two centimetres from the snake, the snake will start to move upwards towards it.

"The charge in the balloon causes the snake to stick to it"

In summary...

Every object contains positive protons and negative electrons. Normally, these are equal, but rubbing the balloon on the wool gives it more negative electrons. These electrons repel the negative electrons in the snake, positively charging its head and causing them to attract.

© Illustrations by Ed Crooks



Kitchen friendly

Triby features a robust splash-proof and dirt-proof design, and strong magnetic back to attach to the fridge.

Sticky notes

Messages, emoji and freestyle drawn doodles can be sent to Triby via its dedicated app and are displayed via the E-Ink display.

WIN!

A connected kitchen speaker worth £159

Using Amazon's Alexa Voice Service, you can get Triby to play music, set alarms, relay the news and weather and control smart home devices using just your voice. Just say 'Alexa' and then your command, and Triby will respond.

What is the name of the self-aware artificial intelligence system in the Terminator franchise?

- a) **Spynet**
- b) **Pienet**
- c) **Skynet**



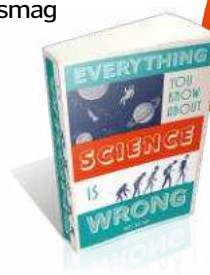
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Letter of the Month

Hot topic

Dear HIW,

I have been subscribing to your magazine for more than two years now and always look forward to the next issue. I've been wondering why your mouth doesn't get burnt when you drink hot tea, but if you spill it on to your skin you get scolded? Hope you can answer this for me. If so, thank you!

Chris Robinson, age 11

P.S. Keep up the great work!

Good question Chris! As you point out, liquids like tea and coffee would definitely scold our skin at these temperatures, so why can we still drink them?

One reason is that while hot drinks are often prepared at temperatures between 80 to 100 degrees Celsius, people tend to wait until the drink cools slightly. For

example, in one study with coffee drinkers, the average temperature the participants preferred to start drinking was around 60 degrees Celsius. However, this is still above the burn damage threshold.

To investigate further, another study tested the temperature of coffee while it was in the mouth, using electronic sensors. The results suggested that duration of exposure was an important factor in why we seem to be able to withstand heat in our mouths better than on our skin. When it's sipped or slurped, tea, coffee and other hot liquids aren't held in the mouth long enough to cause tissue damage. It's also thought that saliva provides an insulating coating, decreasing the risk of scolding sensitive tissue.



The brewing temperature of coffee and tea is above our skin's thermal pain and damage thresholds

What's happening on...

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@MulliganMullet

@HowItWorksmag I hope they name one #VenusVille? #TotalRekall

@SarkaVobornikov

HOW EXCITING!!! - Check out How It Works, Flying cars: the future is now

@TEDTalks

"I'm not trying to be anyone's savior. I'm just trying to think about the future and not be sad." @elonmusk #TED2017

@neiltyson

Evidence that Humans are smarter than Cats: We don't chase Laser dots on the carpet. We're not afraid of Vacuum Cleaners.

@MarsCuriosity

For the science, for the glory, and for the fun... mostly for the science.

@BillGates

Vaccines reach more children than ever. If we set our sights high, we can give every child a shot at life. #VaccinesWork

@ScienceMarchDC

It's been 1 week since we marched for science, & we're already turning the historic moment of April 22 into a historic movement together.

Empty space

Dear HIW,

I love your magazine and I have a subscription so I never miss an issue. A couple of weeks ago I had a random thought: how much gas would planet Earth or multiple planets have to expel in order to fill space so that it was no longer a vacuum?

Liam Cooper

90 tons of matter leak out of the Earth's atmosphere every day as the gas molecules escape our planet's gravity. Known as atmospheric escape, this process happens on all of the planets in the Solar System that have atmospheres. This is only a tiny amount, though, and nowhere near enough to fill the entirety of

space - the observable universe alone is estimated to be 880 sextillion kilometres wide (880 followed by 21 zeroes!), and the entire cosmos may be infinite. Even if all the matter from every planet and star in existence was all ejected at once, it still wouldn't be close to filling space!



Mercury and Mars have mostly lost their atmospheres due to solar winds

Can we melt wood?

Dear HIW,

I have been reading your magazine for ten months now. My favourite part is always Letters of the Month. My question is: can you turn wood into other states of matter such as gas, liquid or plasma? If it's possible, how? If it is not possible, then why not?

Thanks!

Jamil Yacoubou, age 12

Unlike other substances, such as H₂O, which can exist as ice, water or vapour, the constituent molecules in wood decompose rather than melt. In a process called pyrolysis, the material oxidises before it has the chance to melt and the molecules that make up wood change into charcoal, water and carbon dioxide. While it would theoretically be possible to melt wood under high pressures (to lower the melting point of carbon) no laboratories have attempted to do so yet.



Wood's chemical composition changes irreversibly when heated, so it can't melt under normal conditions

The lunar cycle explained

Dear HIW,

Why is it sometimes only possible to see part of the moon?

Many thanks,

Ffion Gomersall

A lunar cycle lasts 29.5 days as the Moon completes a full orbit of the Earth. A new Moon is at the start of the cycle and occurs when the Moon is between the Earth and Sun, so we cannot see the side that is

illuminated by sunlight. As the Moon continues its orbit around the Earth, its position relative to the Sun changes, so different sections are illuminated from our point of view. First we see a slim crescent, then a half Moon, a gibbous Moon and finally a full Moon, where the Earth is between the Sun and Moon so the entire lunar face is illuminated. The phases are then reversed as the Moon goes from full to new again, each section lasting around 7.4 days.

The Moon rotates on its own axis at roughly the same speed as Earth rotates



HOW IT WORKS

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